Final

Record of Decision
Operable Unit 15, Site 88

Marine Corps Base Camp Lejeune
North Carolina
April 2019

1 Declaration

1.1 Site Name and Location

This Record of Decision (ROD) document presents the Selected Remedy for Operable Unit (OU) 15, Site 88 at Marine Corps Base (MCB) Camp Lejeune, located in Onslow County, North Carolina. MCB Camp Lejeune was placed on the United States Environmental Protection Agency (USEPA) National Priorities List (NPL) effective November 4, 1989 (USEPA ID: NC6170022580).

1.2 Statement of Basis and Purpose

The remedy for Site 88 was selected in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986, and to the extent practicable, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).

This decision is based on information contained in the Administrative Record (AR) file for this site. Information not specifically summarized in this ROD or its references, but contained in the AR, has been considered and is relevant to the selection of the remedy at OU 15, Site 88. Thus, the ROD is based upon and relies upon the entire AR file in making the decision. As a result of the NPL listing, and pursuant to CERCLA, the USEPA Region 4, the North Carolina Department of Environmental Quality (NCDEQ), the Department of the Navy (Navy), and the United States Marine Corps (USMC) entered into a Federal Facilities Agreement (FFA) for MCB Camp Lejeune in 1991. The primary purpose of the FFA is to ensure that the environmental impacts associated with past and present activities at MCB Camp Lejeune are thoroughly investigated and response actions taken when necessary to protect human health and the environment. The Installation Restoration Program (IRP) is responsible for ensuring that appropriate CERCLA response alternatives are developed and implemented as necessary to protect public health, welfare, and the environment. No enforcement activities have been recorded at Site 88.

The Navy is the lead agency and provides funding for site cleanups at MCB Camp Lejeune. The remedy set forth in this ROD has been selected by the Navy, USMC, and USEPA. NCDEQ, the support regulatory agency, actively participated throughout the investigation process and, hence, has reviewed this ROD and the materials on which it is based and concurs with this Selected Remedy.

1.3 Scope and Role of Response Action

OU 15 is one of 25 OUs that are part of the comprehensive environmental investigation and cleanup currently being performed at MCB Camp Lejeune under the CERCLA program. OU 15 is solely comprised of Site 88. This ROD documents the Selected Remedy for Site 88. The status of all the IRP sites at MCB Camp Lejeune can be found in the current version of the Site Management Plan, which is located in the AR.

1.4 Selected Remedy

1.4.1 Assessment of the Site

Previous investigations have identified the following:

- **Chemicals of concern** (COCs) including tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (cis-1,2-DCE), and vinyl chloride (VC) in groundwater at concentrations that pose a potential threat to human health if used as a potable water supply and PCE, TCE, and VC through the vapor intrusion (VI) pathway.
- COCs in soil gas, including PCE, TCE, and VC, that pose a potential threat to human health from exposure through the VI pathway and direct exposure during construction.
- PCE in indoor air at Building 3B and TCE in indoor air at Building HP57 that pose a potential threat to human health. A **vapor intrusion mitigation system (VIMS)** was installed in Building 3B and a sewer ventilation system was installed in Building HP57 to mitigate the human health risks associated with the VI pathway. Additionally, VIMS were installed in Buildings 3, 37, and 43 as precautionary measures. All the VIMS are successfully intercepting the VI pathway.
- Dense non-aqueous phase liquid (DNAPL) in the source area and groundwater concentrations in excess of one percent of the solubility of PCE, which is indicative of the presence of DNAPL and considered principal threat waste (PTW).

The response action for Site 88 addresses COC contamination in site media. The response action selected in this ROD is necessary to protect the public health or welfare or the environment from actual or threatened releases of hazardous substances into the environment.

The site has been divided into **three treatment zones**: Zone 1 is defined as the location of the initial source area (former Building 25) with relatively high concentrations of COCs in groundwater at 5 to 60 feet below ground surface (bgs); Zone 2 is downgradient from Zone 1 and includes COC concentrations in groundwater exceeding cleanup goals at depths ranging from approximately 40 to 180 feet bgs. Zone 3 is the downgradient portion of the plume, with impacts limited to approximately 40 to 60 feet bgs, likely due to a higher transmissivity of groundwater in the upper Castle Hayne (UCH) aquifer.

The Selected Remedy to treat COCs at Site 88 include:

- Zone 1: **Enhanced reductive dechlorination (ERD)** via vertical injection wells to treat areas with PTW and groundwater with high COC concentrations at shallow depths near the source area.
- Zone 2: **In-situ chemical oxidation (ISCO)** via horizontal injection wells to treat areas with suspected PTW and groundwater with high COC concentrations at deeper depths downgradient from the source area.
- Zone 3: **Biobarrier** via vertical injection wells to treat the furthest downgradient groundwater contamination.
- VI: Treatment of PTW and groundwater is expected to reduce groundwater concentrations below levels that result in VI pathways of concern. In the interim, continued operation and monitoring of the VIMS at Building 3B, and the sewer ventilation system at Building HP57 will mitigate the VI pathway. As a precautionary measure, continued operation and monitoring of VIMS at Buildings 3, 37, and 43 will mitigate the potential for the VI pathway to become significant in the future.

Land use controls (LUCs) will be implemented to prevent exposure to COCs in contaminated media. After active treatment is complete in each zone, **monitored natural attenuation (MNA)** will be implemented to monitor the COCs in groundwater until cleanup levels are attained and remedial action objectives (RAOs) are satisfied.

1.4.2 Statutory Determinations

The Selected Remedy is protective of human health and the environment, complies with Federal and State regulations that are applicable or relevant and appropriate to the remedial action (RA), is cost-effective, and utilizes permanent solutions and alternative treatment technologies to the maximum extent practicable. This remedy also satisfies the statutory preference for treatment as a principal element of the remedy (i.e., reduces the toxicity, mobility, or volume of hazardous substances, pollutants, or contaminants as a principal element through treatment). Because this remedy will result in hazardous substances, pollutants, or contaminants remaining onsite in groundwater and soil gas above levels that allow for unlimited use and unrestricted exposure, a statutory review will be conducted within five years after the initiation of the RA to ensure that the remedy is, or will be, protective of human health and the environment in accordance with CERCLA Section 121(c) and the NCP at 40 Code of Federal Regulations (CFR) 300.430 (f)(4)(ii).

1.5 Data Certification Checklist

The following information is included in the Decision Summary section of this ROD. Additional information can be found in the AR[A] file for MCB Camp Lejeune, Site 88.

- COCs and their respective concentrations (**Section 2.7**, **Table 7**)
- Baseline risk represented by the COCs (**Section 2.7**)
- Cleanup levels established for COCs and the basis for these levels (**Section 2.9**)
- How source materials constituting principal threats will be addressed (**Section 2.8**)
- Current and reasonably anticipated future land use assumptions and current and potential future beneficial uses of groundwater used in the baseline risk assessment and ROD (**Section 2.4**)
- Potential land and groundwater use that will be available at the site as a result of the Selected Remedy (**Section 2.11.3**, **Table 16**)
- Estimated capital, annual operation and maintenance (O&M), and total present worth costs, discount rate, and the number of years over which the remedy cost estimates are projected (**Section 2.10**)
- Key factor(s) that led to selecting the remedy (i.e., describe how the Selected Remedy provides the best balance of tradeoffs with respect to the balancing and modifying criteria, highlighting criteria key to the decision) (**Section 2.11.1**)

If contamination posing an unacceptable risk to human health or the environment is discovered after execution of this ROD, the Navy will undertake all necessary actions to protect human health and the environment.

A **Bold blue text** identifies detailed site information available in the Administrative Record and listed in the References Table.

1.6 Authorizing Signatures

This ROD presents the Selected Remedy at OU 15, Site 88 at MCB Camp Lejeune, located in Onslow County, North Carolina.

S. A. BALDWIN — 20 May 2019 (Date)
Colonel, U.S. Marine Corps
Commander, Acting
Marine Corps Installations East – Marine Corps Base Camp Lejeune

Franklin E. Hill, Director — 5/23/19 (Date)
Superfund Division
United States Environmental Protection Agency, Region 4

With concurrence from:

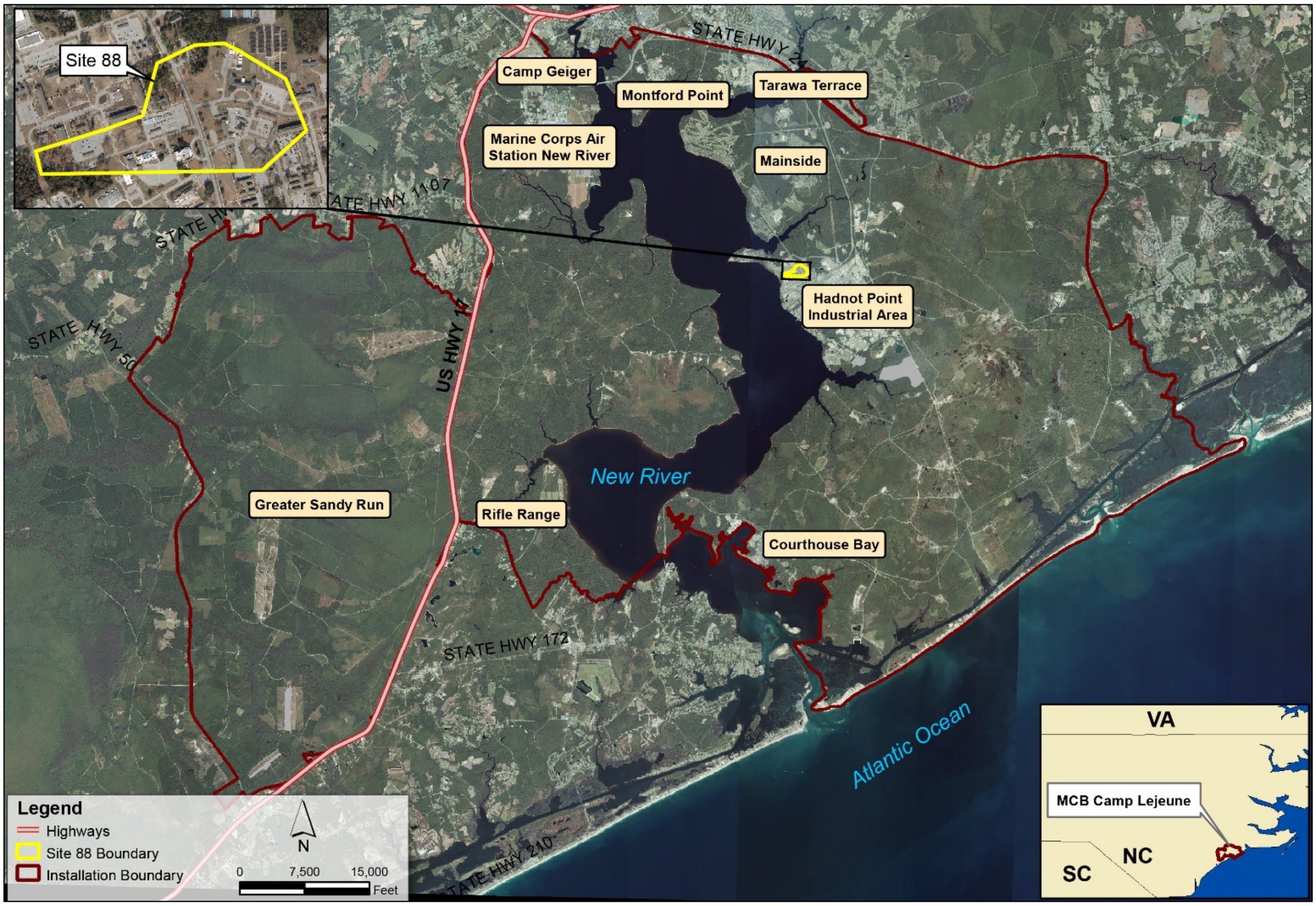
Michael Scott — 5/28/19 (Date)
Director, Division of Waste Management
North Carolina Department of Environmental Quality

2 Decision Summary

2.1 Site Description and History

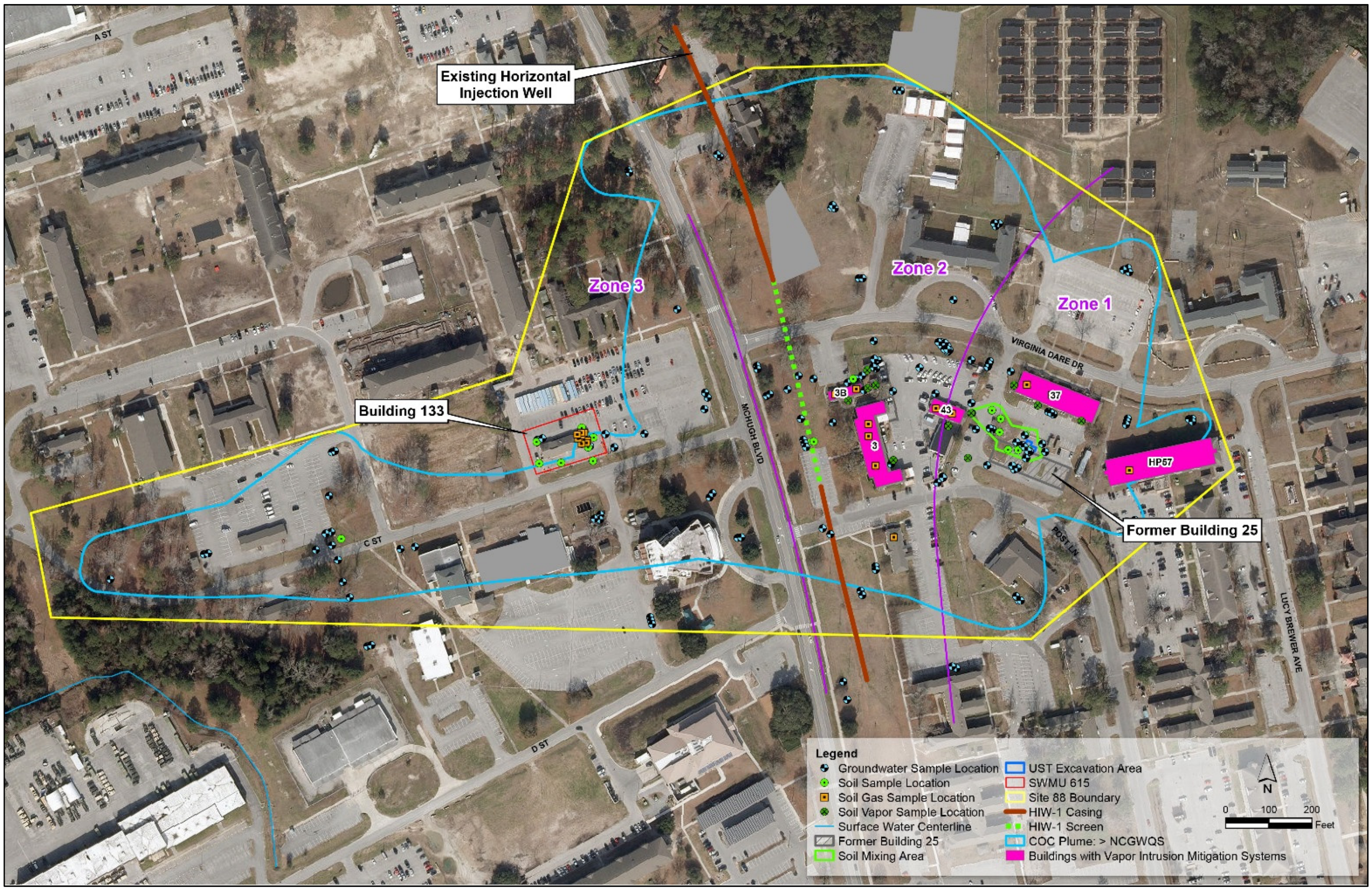
MCB Camp Lejeune is a 156,000-acre facility located in Onslow County, North Carolina, adjacent to the southern side of the City of Jacksonville (**Figure 1**). The mission of MCB Camp Lejeune is to maintain combat-ready units for expeditionary deployment. MCB Camp Lejeune provides housing, training facilities, and logistical support for Fleet Marine Force Units and other assigned units.

FIGURE 1
Base Location Map



Site 88 is approximately 51 acres and is located on the Mainside area of MCB Camp Lejeune (**Figure 1**). The site consists of former Building 25, which operated as a dry cleaning facility from the 1940s to 2004, and the surrounding paved and grassy areas extending west, northeast, and south of the former Building 25 location. Site 88 is located in a developed area and is surrounded by buildings, parking lots, streets, and sidewalks. Buildings surrounding former Building 25 include administrative offices and barracks (**Figure 2**). The suspected source of contamination at Site 88 is the historical dry cleaning operations at former Building 25. Five **underground storage tanks (USTs)** were installed on the north side of the building to store dry cleaning fluids. Initially, **Varsol**, a petroleum-based product, was used in dry cleaning operations at former Building 25. Because of flammability concerns, Varsol's use was discontinued in the 1970s and it was replaced with **PCE**. The PCE was stored in one 150-gallon aboveground storage tank (AST) adjacent to the north wall of former Building 25, in the vicinity of the USTs. PCE was reportedly stored in the AST from the 1970s until the mid-1980s. During this time, facility employees reported that PCE was disposed of in floor drains. In March 1995, self-contained dry cleaning machines were installed in former Building 25, eliminating the need for bulk storage of PCE, and the USTs and AST were removed. The dry-cleaning operations ceased in January 2004, and the building was demolished to slab in August 2004.

FIGURE 2
Site Map

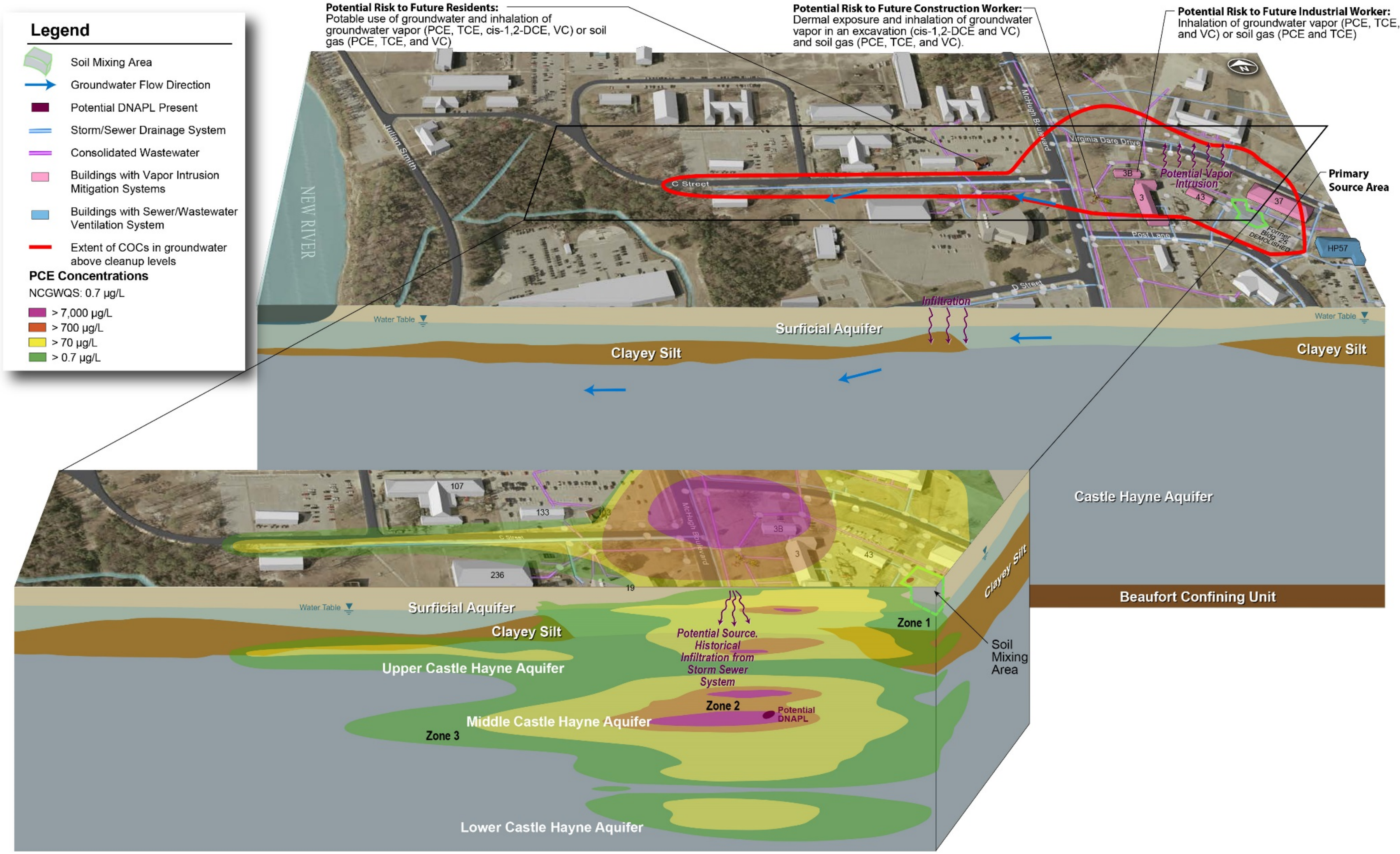


2.2 Site Characteristics

Site 88 is located within the industrial area of the Base, with little topographic relief. Ground surface elevations range from approximately 20 to 30 feet above mean sea level. Site 88 is primarily covered by asphalt or concrete, with smaller areas of maintained grass between the buildings, roads, and parking areas. Infiltration is limited at the site and the surface water drainage is conveyed through a series of storm sewers, located along the roads, to the New River. An underground sewer system emanates from the former dry cleaning facility, connecting several of the buildings in this area.

The site is underlain by four distinct geologic formations (undifferentiated sediments, the Belgrade Formation, the River Bend Formation, and the Castle Hayne Formation) which correspond to the surficial aquifer, Castle Hayne confining unit, UCH aquifer, middle Castle Hayne (MCH) aquifer, and lower Castle Hayne (LCH) aquifer, respectively (**Figure 3**). The undifferentiated sediments from ground surface to approximately 25 feet bgs consist primarily of fine sand and silt. The Belgrade Formation underlying the undifferentiated sediments, consists of 5- to 7-feet thick laterally discontinuous layers of silty clay and clayey silt at the site. Underlying the Belgrade Formation are the River Bend Formation, and the Castle Hayne Formation, which generally consist of mostly fine sands, silts, and clays, with lesser amounts of shell fragments.

FIGURE 3
Conceptual Site Model



The aquifer **hydrogeologic units** at Site 88 have been designated as four zones corresponding to the following depths: surficial (5 to 25 feet bgs), UCH (25 to 75 feet bgs), MCH (75 to 125 feet bgs), and LCH (125 to 180 feet bgs). The surficial aquifer is composed of undifferentiated sediments and is underlain by the Castle Hayne confining unit or Belgrade Formation, as described above. The Castle Hayne confining unit is not present continuously at the site and in areas where it is absent, the surficial aquifer and the Castle Hayne aquifer are in direct hydraulic communication. The Castle Hayne confining unit is present under former Building 25 at approximately 20 feet bgs with a variable thickness of approximately 14 to 16 feet. This unit appears to decrease in thickness significantly to the northeast and again to the southwest, and is discontinuous to the west of former Building 25. The Castle Hayne confining unit is underlain by the Castle Hayne aquifer (River Bend and Castle Hayne Formations).

Groundwater flow in the surficial aquifer is highly variable and is likely influenced by differing hydraulic conductivity of the undifferentiated sediments. The UCH and MCH aquifers flow to the west and northwest toward the New River. Based on the limited data, the inferred groundwater flow direction in the LCH is to the southwest. The average hydraulic conductivity (groundwater velocity) in the surficial aquifer is 4.1 feet per day. The average hydraulic conductivities in the UCH and MCH aquifers are 14.7 feet per day and 7.9 feet per day, respectively.

2.3 Previous Investigations, Studies, and Removal Actions

Site 88 was characterized under numerous investigations and studies between 1995 and 2018. **Table 1** presents a chronological list of those studies and interim actions taken to address site contamination. During these investigations, 80 subsurface soil samples were collected and one or more samples were collected from 35 soil gas locations, 18 indoor air locations, and 158 permanent monitoring wells for laboratory analysis (**Figure 2**). The Site 88 **conceptual site model (CSM)** (**Figure 3**) depicts the site characteristics, nature and extent of contamination, and transport pathways. The respective investigations are a part of the AR and can be referenced for further details for specific sampling strategies, media investigations, and when and where sampling was performed.

TABLE 1
Summary of Previous Investigations, Studies, and Removal Actions

Previous Investigation/ Study, Removal Actions	Administrative Record Numbers	Dates	Activities and Findings
Underground Storage Tank and AST Removal (OHM Remediation Services Corporation, 1996)	001738, 001739	1995	Five USTs and one AST were removed at former Building 25. A limited investigation was completed, and chlorinated solvents, metals, and petroleum hydrocarbons were detected in soil and groundwater.
Focused Remedial Investigation (RI) (Baker, 1998)	002032	1996-1998	The Focused RI was conducted to investigate soil and groundwater. Subsurface soil contamination was identified under and near Building 25, and adjacent to an underground sewer line. Groundwater contamination was identified in the surficial aquifer and the upper portion of the Castle Hayne aquifer. Building 25 was identified as the source area, and the primary contaminants were chlorinated solvents and other volatile organic compounds (VOCs). Concentrations in the source area suggested the presence of DNAPL.
DNAPL Site Characterization Using Partitioning Interwell Tracer Tests (Duke Engineering and Services, 1999)	002324	1997-1998	A **DNAPL source investigation** for PCE included soil and groundwater sampling, cone penetrometer testing, and tracer testing. Before the tracer test, approximately 30 to 60 gallons of free-phase DNAPL were extracted from the test area. The tracer test identified DNAPL saturation north of and directly under former Building 25 at depths ranging from 16 to 20 feet bgs. The volume of DNAPL remaining after removal during this investigation was estimated at 74 to 88 gallons. A light non-aqueous phase liquid plume was also observed from 7 to 10 feet bgs.

TABLE 1

Summary of Previous Investigations, Studies, and Removal Actions

Previous Investigation/ Study, Removal Actions	Administrative Record Numbers	Dates	Activities and Findings
Surfactant Enhanced Aquifer Remediation (Duke Engineering and Services, 2000)	004618	2000	**Surfactant was continuously injected** into a 20-foot by 30-foot treatment area on the northern side of former Building 25 and extracted along with approximately 76 gallons of PCE, mostly from the surficial and UCH aquifers. Limited removal was observed in the low permeability soil.
Reductive Anaerobic Bioremediation In Situ Treatment Technology (Battelle Memorial Institute, 2001, 2003)	004778, 007220	2000-2001	Treatability testing was performed northwest of former Building 25 to evaluate whether reductive dechlorination (biodegradation) could be stimulated in situ. PCE-contaminated groundwater was extracted from a UCH monitoring well, amended with an electron donor solution of **butyric acid and yeast extract**, then re-injected into injection wells screened in the UCH aquifer. Groundwater downgradient from the injection wells was analyzed for 30 weeks following treatment. Results indicated microbial populations were capable of degrading PCE to ethene.
Supplemental Investigations (CH2M, 2004)	004000	2002-2004	From 2002 to 2003, a sewer survey, aquifer testing, natural gamma borehole logging, and groundwater sampling were completed to assess the nature and extent of the contamination in the surficial and Castle Hayne aquifers. The results indicated that site contaminants were migrating laterally to the northwest within the surficial and Castle Hayne aquifers, and DNAPL was migrating vertically. The **sewer survey** also identified several areas where the integrity of the joints was considered significantly compromised; joints are potential DNAPL migration pathways. In 2004, a membrane interface probe investigation was conducted to refine previous source area characterization and conduct vertical soil profiling near former Building 25 and the nearby sewer systems. Information provided by the membrane interface probe investigation was used to evaluate the horizontal and vertical distribution of the DNAPL source area and along the sewer lines. The results of these investigations were used to identify the treatment area for a non-time-critical removal action (NTCRA).
Engineering Evaluation/ Cost Analysis (EE/CA) and NTCRA (CH2M, 2004; AGVIQ/CH2M Joint Venture, 2006)	004000, 003954	2004-2006	An EE/CA was completed to evaluate removal action alternatives for treating DNAPL, particularly PCE, in the source area soil and surficial aquifer groundwater to approximately 22 feet bgs. **Shallow soil mixing** with clay and zero-valent iron (ZVI) was the recommended technology. In 2005, the NTCRA was completed by treating approximately 7,050 cubic yards of contaminated soil. The soil mixing area is shown on **Figure 2**. Within the treatment area, PCE concentrations in soil were reduced by greater than 99 percent. Despite the source area PCE concentration reduction, residual dissolved phase groundwater contamination remained over approximately 50 acres of the surrounding and downgradient areas.
RI (CH2M, 2008)	004120, 004121	2005-2008	An expanded groundwater investigation was completed in 2005. PCE concentrations were higher in the Castle Hayne aquifer than in the surficial aquifer, indicating vertical migration. Additionally, it was concluded that DNAPL may be present in the deeper aquifer zones. Potential human health risks from chlorinated VOCs were identified in groundwater. No unacceptable ecological risks were identified.

TABLE 1
Summary of Previous Investigations, Studies, and Removal Actions

Previous Investigation/ Study, Removal Actions	Administrative Record Numbers	Dates	Activities and Findings
Basewide VI Evaluation (AGVIQ/CH2M Joint Venture, 2009; CH2M, 2011; CH2M, 2012; CH2M, 2015a)	002772, 002773, 004694, 004695, 005425, 005910	2007-2015	Site 88 was included in the **phased Basewide VI evaluation**, conducted from 2007 to 2011, to determine whether complete or significant exposure pathways exist for VI into buildings. Buildings 3, 3B, 4, 6, 19, 37, 41, 43, 67, 80, 113, 147, 236, 254, HP56, HP57, and S94 were evaluated. VI was identified as a pathway of concern at Building 3B, and a VIMS was installed in 2012. Although VI was not a significant pathway of concern, there was a potential for the VI pathway to become significant at Buildings 3, 37, and 43 in the future. Based on the results of the evaluation, the Base elected to install a VIMS in Buildings 3, 37, and 43 in 2012, as a precautionary measure. **VIMS O&M was initiated in 2012** and is ongoing. Additional sampling was conducted at Building HP57 and Building 37A (identified based on exceedances of groundwater in the vicinity) in 2013. Based on the results, no further action was recommended for Building 37A, and follow-up monitoring was recommended at Building HP57.
Geophysical Survey (CH2M, 2009)	004777	2009	A **geophysical survey** was conducted near former Building 25 to identify anomalies indicative of a UST. No anomalies were detected that suggested the presence of any USTs.
Polymer-Enhanced Subsurface Delivery and Distribution of Permanganate (ESTCP, 2013)	007576	2009-2012	A field study was conducted from 2010 to 2011 in the source area, outside of the soil mixing area. The primary objective was to demonstrate the use of the polymer amendments xanthan gum and sodium hexametaphosphate to enhance the treatment efficiency of in situ permanganate remediation. Results indicated that the **viscosity modification** via polymer addition can potentially mitigate preferential flow effects and enhance the overall distribution of permanganate. During this field study, DNAPL was encountered outside of the soil mixing area in Zone 1.
ISCO, ERD, and Biobarrier Pilot Studies (CH2M, 2017)	007285	2010-2011	Bench-scale tests were conducted to identify optimal oxidants for ISCO and substrates for ERD based on site-specific conditions, as a means of addressing the PCE contamination in groundwater in preparation for the Feasibility Study (FS). **Pilot-scale tests** were conducted using the bench-scale recommendations for each zone as follows: Zone 2 UCH: ISCO using permanganate reduced PCE concentrations by 86.7 percent in the treatment zone. Zone 2 MCH (deeper aquifer): ERD using an emulsified vegetable oil slow-release substrate and bioaugmentation were not effective. Zone 3 UCH: ERD using a commercial substrate product comprising esterified lactic acid and long chain fatty acids in a biobarrier configuration effectively reduced PCE concentrations.
Phase I Limited Site Assessment (LSA) (CH2M, 2011)	004779	2011	A **limited site assessment** was conducted near former Building 25 to assess the environmental risks associated with the leakage of petroleum products (Varsol) from UST 25. The study showed that while former UST 25 was a safe distance from drinking or surface water sources, the presence of indeno(1,2,3-cd)pyrene in groundwater prevents the site from qualifying for low-risk classification.

TABLE 1
Summary of Previous Investigations, Studies, and Removal Actions

Previous Investigation/ Study, Removal Actions	Administrative Record Numbers	Dates	Activities and Findings
Solid Waste Management Unit 615 Investigations (CH2M, 2016, NCDEQ, 2016)	006881, 006877	2012-2016	In 2012, stained soil was observed during foundation repair activities at Building 133, located within the boundary of Site 88. The area was investigated under the UST program and later under the Resource Conservation and Recovery Act program as **Solid Waste Management Unit 615**. Contaminated soil was removed in 2013, and as part of the removal action, confirmatory soil and groundwater samples were collected. PCE was detected in soil at concentrations above the North Carolina soil screening level. VC was detected in groundwater at concentrations above the North Carolina Groundwater Quality Standards (NCGWQS), and a VI investigation was initiated for Building 133. The results indicated that there was not a significant VI pathway, and no further VI evaluation was recommended. In 2014, a soil and groundwater investigation was conducted, and PCE and TCE were identified in groundwater at concentrations above screening levels. Because PCE and TCE are also Site 88 COCs, it was recommended that the groundwater associated with Solid Waste Management Unit 615 be managed as part of Site 88. **NCDEQ accepted the recommendation** in January 2016.
VIMS and Performance Monitoring (CH2M, 2012, 2014a, 2014b, 2014c, 2014d, 2015a, 2015b, 2015c, 2016a, 2016b, 2017)	005425, 005910, 005912, 007065, 007069, 006438, 006489, 006721, 007074, 007076, 007084, 007085, 007205, 006472	2012-Present	VIMS were installed in four buildings (3, 3B, 37, and 43) at Site 88 in February 2012. Performance monitoring began in March 2012, and is conducted quarterly to evaluate whether the VIMS at Site 88 are operating to effectively mitigate the VI pathway.
Building HP57 Additional VI Investigation (CH2M, 2015c)	006572	2014-2015	An additional VI investigation was conducted at Building HP57 based on recommendations from the Basewide VI investigations. PCE, TCE, and chloroform were detected in indoor air; however, only TCE was detected at a concentration exceeding the North Carolina Vapor Intrusion Screening Level (VISL). PCE and TCE were detected in subslab soil gas, but at concentrations below the North Carolina VISL for subslab soil gas. Therefore, an investigation using a portable gas chromatograph/mass spectrometer, called a HAPSITE, to collect real-time concentration measurements was conducted to identify the source of the indoor air concentrations in Building HP57. **An uncapped sewer pipe** was identified as a potential pathway for vapor to enter the building, and the pipe was plugged. Because PCE and TCE were found to be present in the sewer line entering Building HP57, the p-traps (the section of pipe beneath a drain inlet that retains water to prevent sewer gases from entering into a building) in Building HP57 were inspected and repaired as necessary by Base Public Works to prevent vapors from entering indoor spaces by maintaining a water barrier. Follow-up sampling was completed, and concentrations of PCE and TCE were not detected in indoor air above screening levels. An additional HAPSITE investigation was conducted following the plumbing repairs in Building HP57 with the objective of confirming the sewer line as a vapor source, as well as, evaluating concentrations of TCE and PCE after sealing the uncapped pipe in Building HP57 and to determine whether vapor transport along the sewer line was impacting other buildings. Thus, HAPSITE

TABLE 1

Summary of Previous Investigations, Studies, and Removal Actions

Previous Investigation/ Study, Removal Actions	Administrative Record Numbers	Dates	Activities and Findings
			investigations also were conducted in Buildings HP55, 37, 58, 59, and 67, which are connected to the same sewer line as Building HP57, per utility drawings. PCE and TCE were not detected above the screening levels in any of these buildings evaluated. However, because of the historical detections of TCE above the North Carolina VISL for indoor air and the USEPA Region 9 Accelerated Response level in Building HP57 and confirmation that the sewer line is a source of vapors, a holistic mitigation approach was recommended, which included venting of the sewer line before entering the building.
Building HP57 Sewer Ventilation Pilot Study (CH2M, 2018b)	007273	2016-2017	A pilot study was initiated at Building HP57 to assess whether **ventilation of the sewer line** could reduce PCE and TCE concentrations within the sewer line between the source area and Building HP57, thus reducing the concentrations in Building HP57 plumbing and indoor air. Overall, the data collected support the conclusion that the permanent sewer ventilation system can mitigate sewer VI at Building HP57.
Permanganate Tracer Study (CH2M, 2017)	007285	2016	A **tracer study** was conducted to evaluate the technical feasibility of permanganate distribution through a horizontal directionally drilled injection well. The study evaluated whether extraction and recirculation would enhance the distribution of permanganate in the MCH aquifer. The data were used to refine design parameters and alternative comparisons in support of the FS. The study indicated that horizontal directionally drilled wells, coupled with the extraction and recirculation system, could effectively deliver and distribute oxidant into the deeper aquifer, and that permanganate is an effective oxidant based on an 82 percent reduction in total COC concentrations in samples collected 10 feet from the injection well.
FS (CH2M, 2017)	007285	2016-2017	The FS was prepared to refine the CSM based on additional investigations and pilot studies conducted at the site, to identify the RAOs and target treatment zones, and to evaluate the remedial alternatives that would satisfy the RAOs. The following remedial alternatives were evaluated for each zone: <u>Zone 1 Alternatives</u> 1. No action 2. Air sparging (AS) with soil vapor extraction (SVE), MNA, LUCs, and VIMS 3. ISCO, MNA, LUCs, and VIMS 4. ERD, MNA, LUCs, and VIMS <u>Zone 2 Alternatives</u> 1. No action 2. AS, MNA, LUCs, and VIMS 3. ISCO, MNA, LUCs, and VIMS <u>Zone 3 Alternatives</u> 1. No action 2. MNA and LUCs 3. Biobarrier, MNA, and LUCs

TABLE 1
Summary of Previous Investigations, Studies, and Removal Actions

Previous Investigation/ Study, Removal Actions	Administrative Record Numbers	Dates	Activities and Findings
Proposed Plan (PP) (CH2M, 2018c)	007644	2018	The PP was issued to solicit public comments on the Preferred Alternative for addressing groundwater contamination at the site, including • Zone 1: ERD via vertical injection wells to treat areas of PTW and groundwater with high COC concentrations at shallow depths near the source area. • Zone 2: ISCO via horizontal injection wells to treat PTW and high COC concentrations at deeper depths downgradient from the source area. • Zone 3: Biobarrier via vertical injection wells to treat the furthest downgradient groundwater contamination. • Zones 1 and 2: Continued operation and monitoring of VIMS at Buildings 3, 3B, 37, and 43 and a sewer ventilation system at Building HP57. • Sitewide: MNA and LUCs. The PP summarized the remedial alternatives evaluated and the rationale for selection of the Preferred Alternative.

2.4 Nature and Extent of Contamination

The nature and extent of contamination at Site 88 is presented for soil, groundwater, DNAPL, and soil gas and indoor air. A CSM is presented on **Figure 3**.

2.4.1 Soil

Investigations conducted prior to 2004 indicated a soil source area in the vicinity of former Building 25. PCE, TCE, cis-1,2-DCE, and VC were detected; PCE was the most widespread (**Figure 4**). This soil source area, estimated to include 9,000 square feet to a depth of 22 feet bgs, was treated by ZVI soil mixing as an NTCRA in 2005.

Soil samples collected after the NTCRA contained VOCs including PCE, TCE, cis-1,2-DCE, VC, benzene, and aromatics C9-C22 at concentrations above Soil-to-Groundwater Maximum Soil Contaminant Concentrations (MSCCs). TCE and cis-1,2-DCE concentrations exceeded the Residential MSCCs and PCE was detected above the Industrial MSCC. The highest concentrations of all chemicals, including PCE up to 25,000 micrograms per kilogram (µg/kg) and aromatics C9-C22 up to 130,000 µg/kg, were reported in samples collected within the ZVI soil mixing area localized around the former UST tank basin, which is currently covered with an asphalt parking lot. Samples were collected at depths within the smear zone or fully submerged in the surficial aquifer.

2.4.2 Groundwater

PCE and daughter products (TCE, cis-1,2-DCE, and VC) and petroleum-related hydrocarbons, including benzene, aliphatics C9-C18, aliphatics C5-C8, aromatics C9-C22, and naphthalene, have been detected at Site 88 in groundwater at concentrations above respective NCGWQS (**Figures 5** through **9**). The extent of these contaminants is discussed by aquifer in the following subsections.

Surficial Aquifer

Groundwater contamination in the surficial aquifer has been delineated laterally and extends from former Building 25 approximately 1,100 feet west (downgradient) across McHugh Boulevard. The vertical extent of contaminants within the surficial aquifer ranges from the water table to approximately 25 feet bgs.

FIGURE 4

PCE in Soil

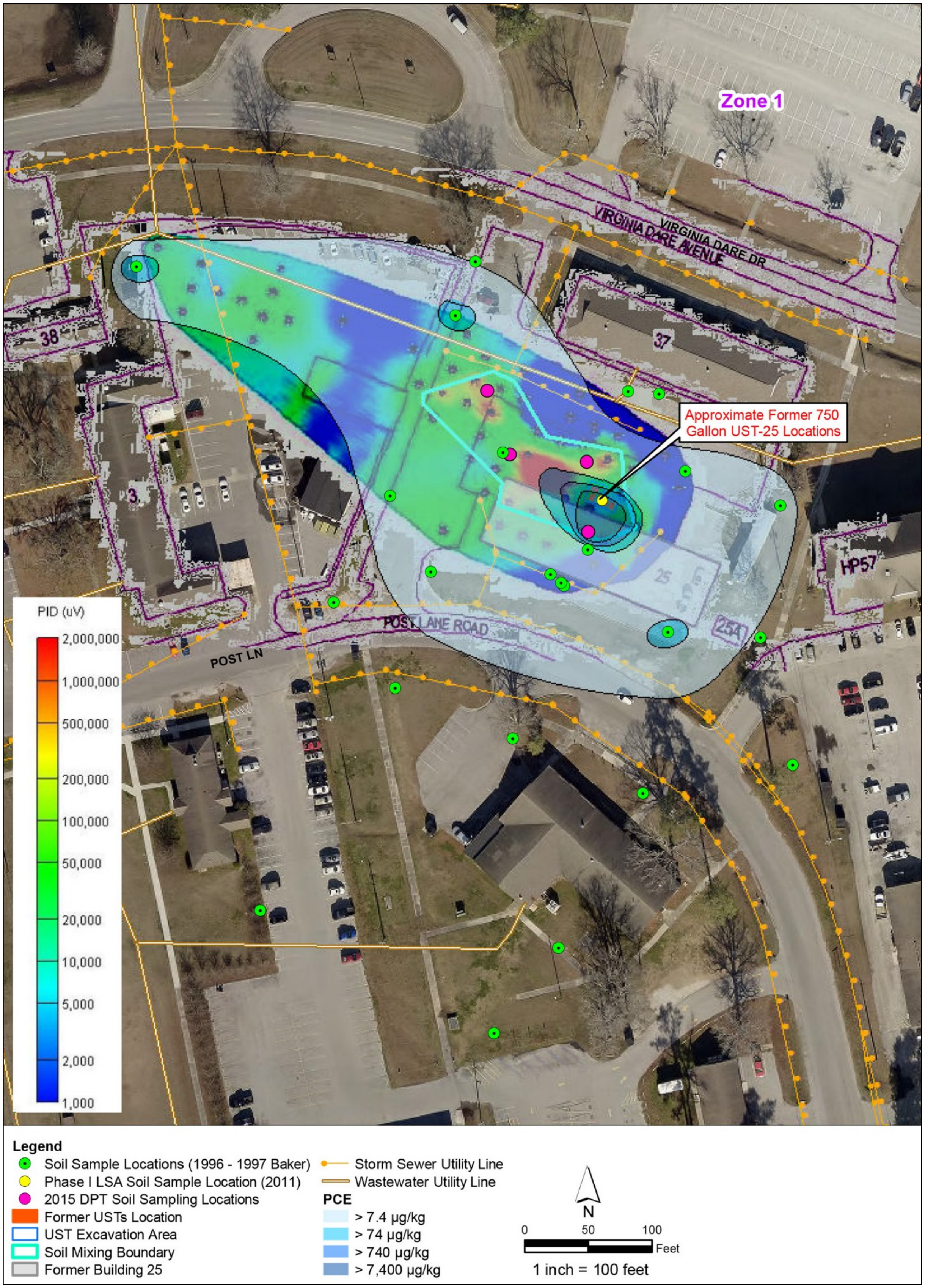


FIGURE 5

PCE In Groundwater

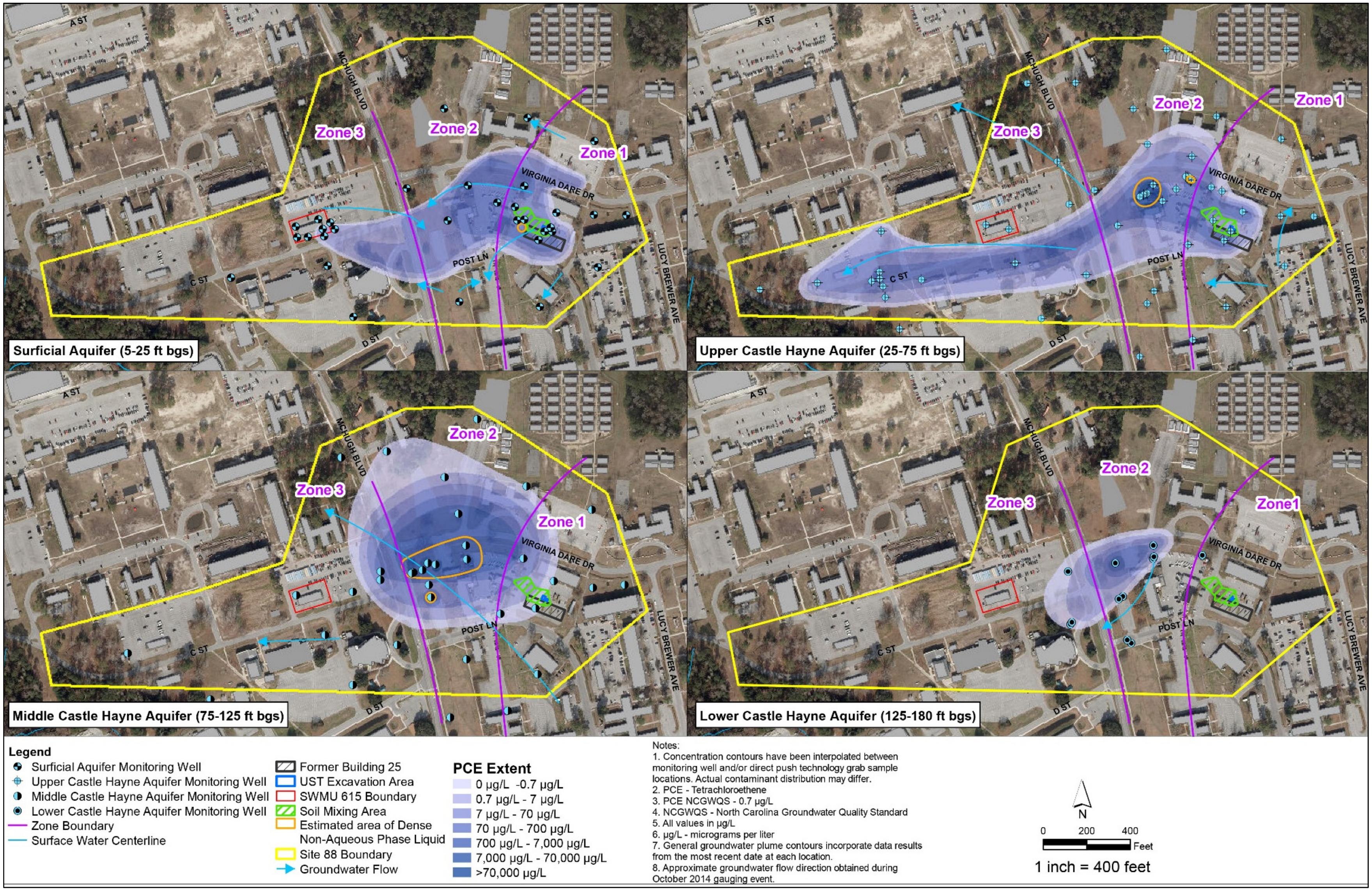


FIGURE 6

TCE in Groundwater

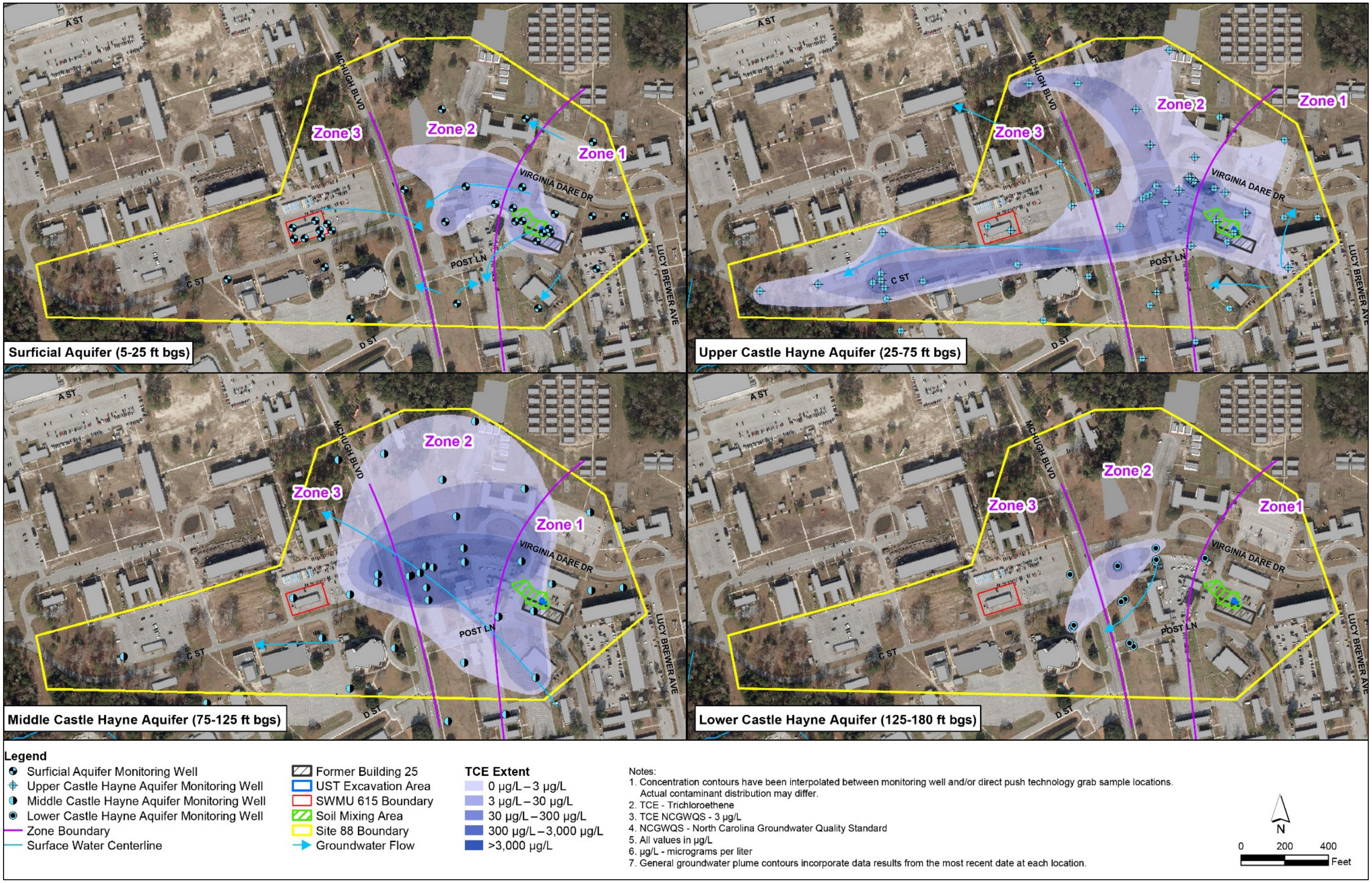
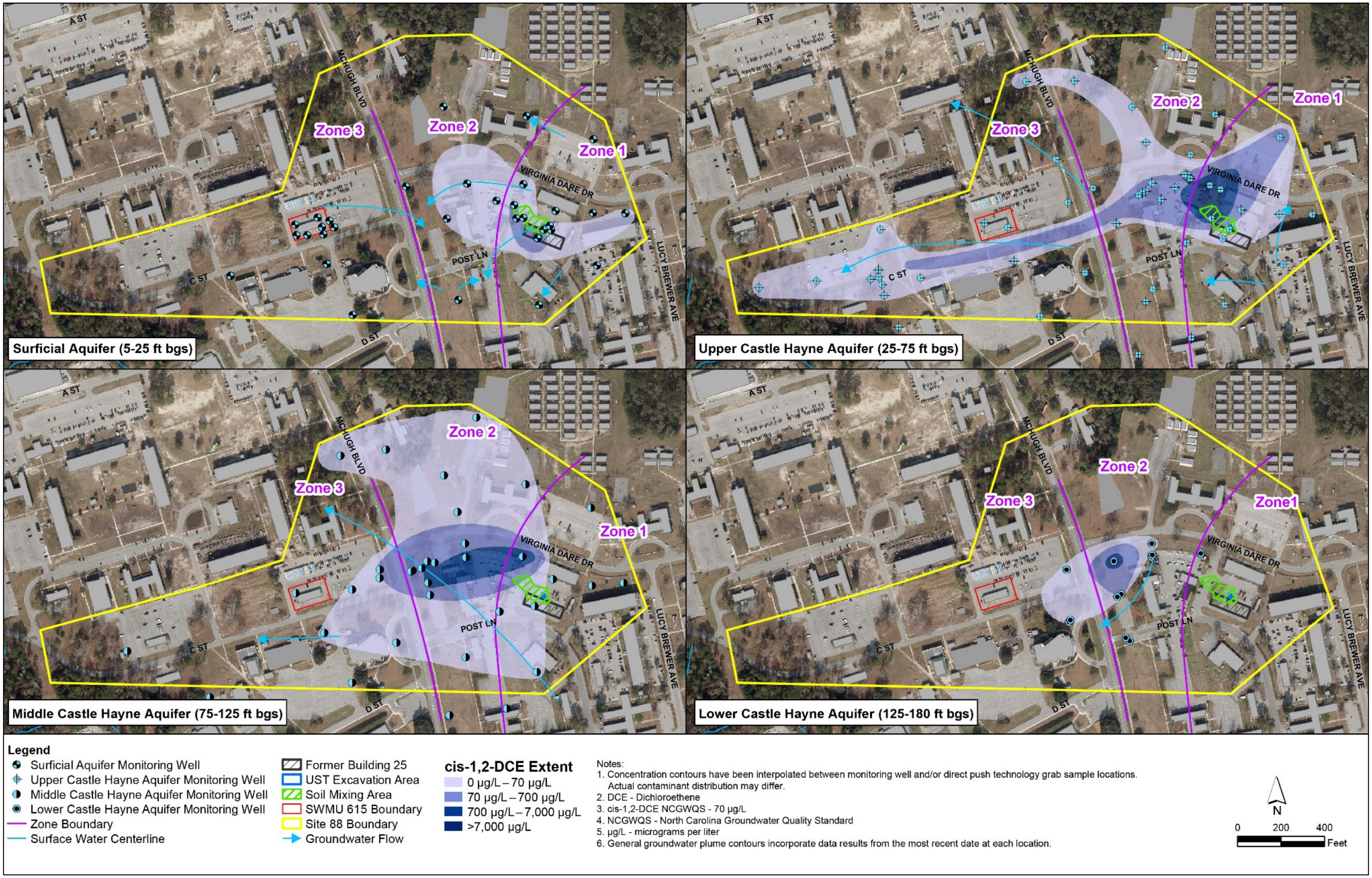


FIGURE 7

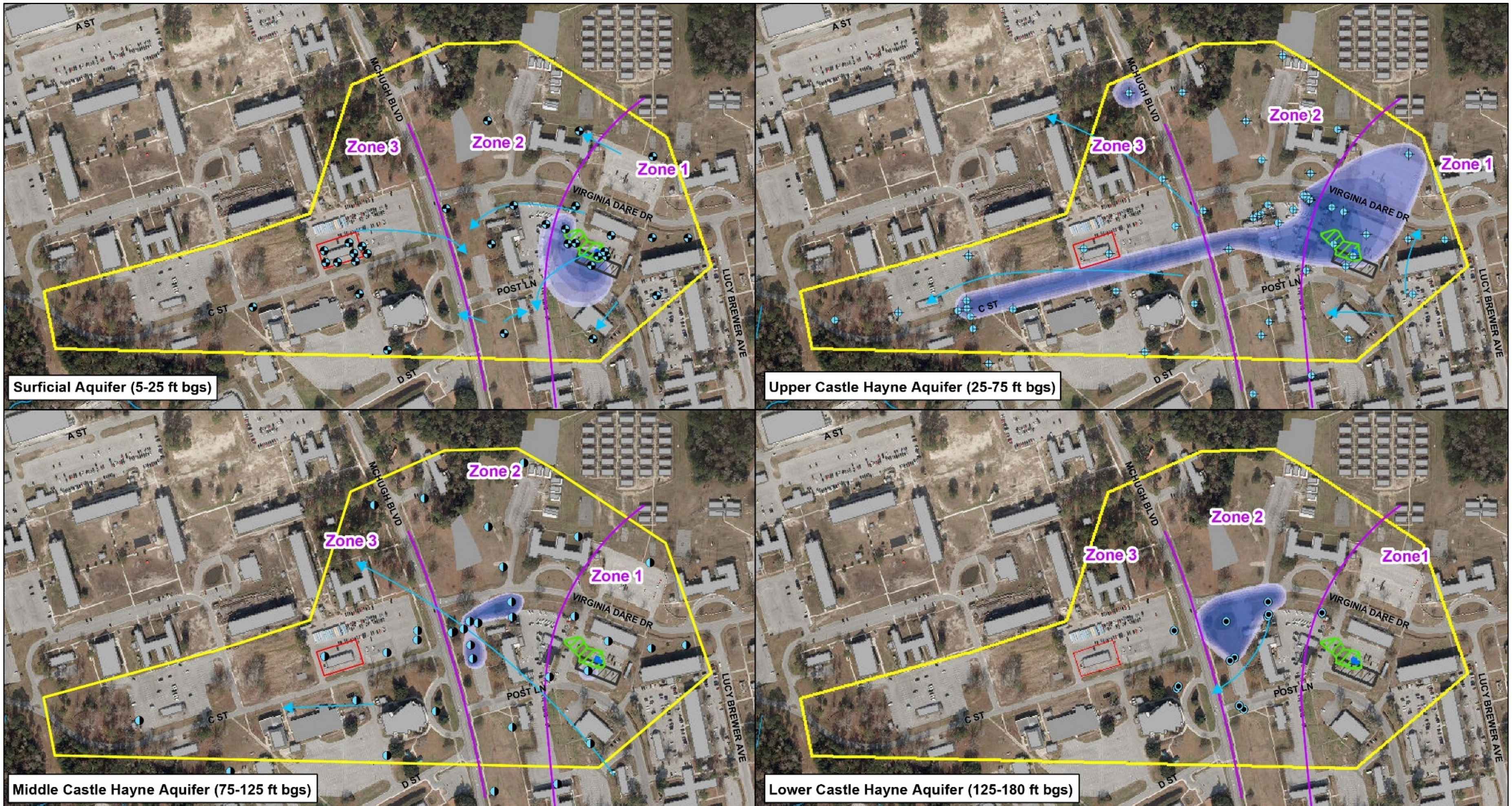
Cis-1,2-DCE in Groundwater



Notes:
1. Concentration contours have been interpolated between monitoring well and/or direct push technology grab sample locations. Actual contaminant distribution may differ.
2. DCE - Dichloroethene
3. cis-1,2-DCE NCGWQS - 70 µg/L
4. NCGWQS - North Carolina Groundwater Quality Standard
5. µg/L - micrograms per liter
6. General groundwater plume contours incorporate data results from the most recent date at each location.

FIGURE 8

VC in Groundwater



Legend

- Surficial Aquifer Monitoring Well
- Upper Castle Hayne Aquifer Monitoring Well
- Middle Castle Hayne Aquifer Monitoring Well
- Lower Castle Hayne Aquifer Monitoring Well
- Zone Boundary
- Surface Water Centerline
- Former Building 25
- UST Excavation Area
- SWMU 615 Boundary
- Soil Mixing Area
- Site 88 Boundary
- Groundwater Flow

VC Extent

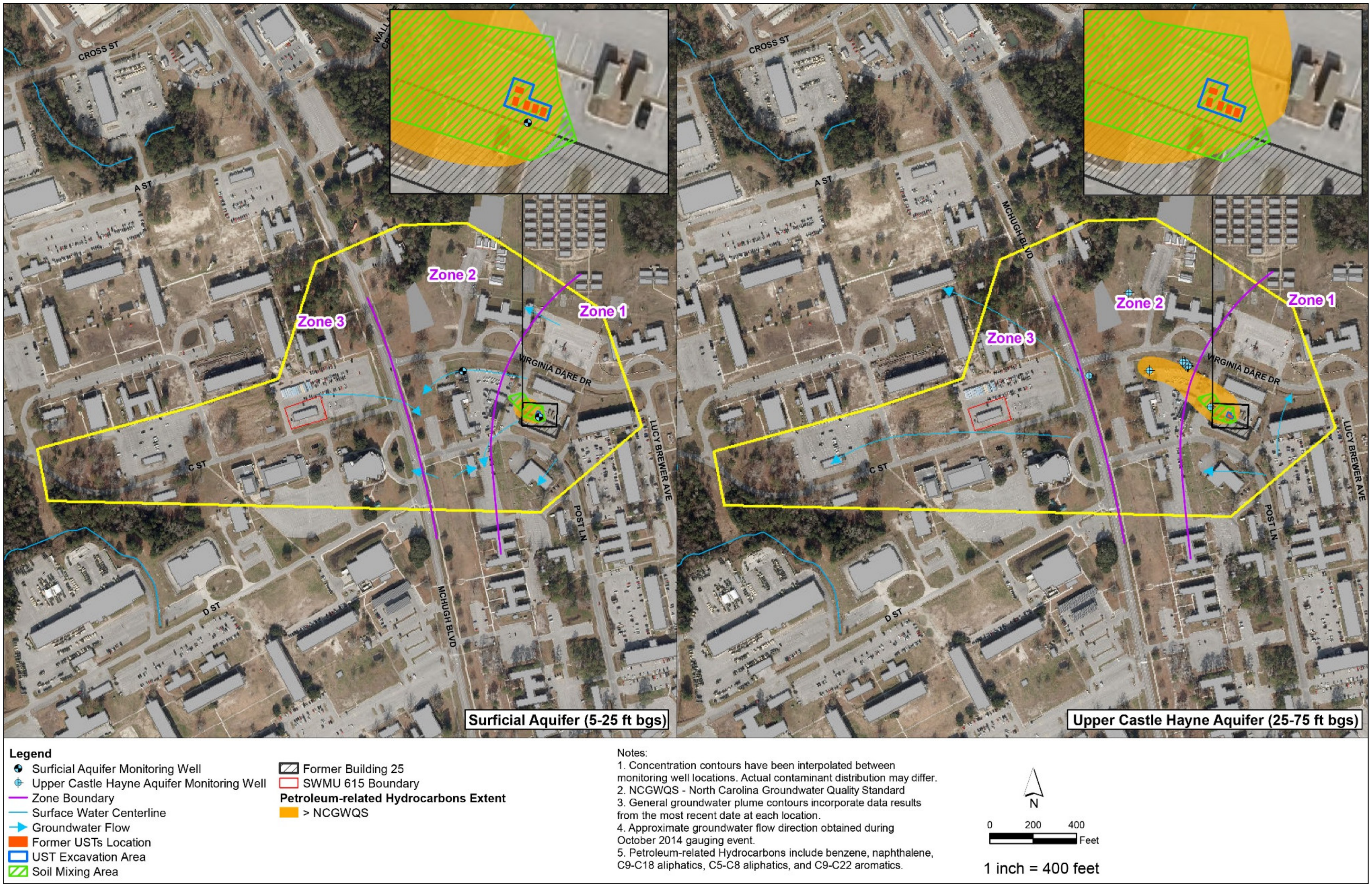
- 0 µg/L – 0.03 µg/L
- 0.03 µg/L – 0.3 µg/L
- 0.3 µg/L – 3 µg/L
- 3 µg/L – 30 µg/L
- 30 µg/L – 300 µg/L
- 300 µg/L – 3,000 µg/L
- >3,000 µg/L

Notes:
1. Concentration contours have been interpolated between monitoring well locations. Actual contaminant distribution may differ.
2. VC - Vinyl Chloride
3. VC NCGWQS - 0.03 µg/L
4. NCGWQS - North Carolina Groundwater Quality Standard
5. All values in µg/L
6. µg/L - micrograms per liter
7. General groundwater plume contours incorporate data results from the most recent date at each location.

N

0 200 400 Feet

FIGURE 9
Petroleum-related Hydrocarbons in Groundwater



PCE was detected above NCGWQS in the surficial aquifer at concentrations ranging from below the laboratory detection limit to 479 micrograms per liter (µg/L). The plume extends across McHugh Boulevard, following the former sewer lines (**Figure 5**). TCE, cis-1,2-DCE, and VC, are also present at concentrations exceeding NCGWQS. The footprint of the daughter products is smaller and generally contained within that of PCE. The highest concentrations of TCE (54 µg/L), cis-1,2-DCE (4,990 µg/L), and VC (1,210 µg/L) are located immediately adjacent to the ZVI soil mixing area (**Figures 6** through **8**).

Petroleum-related compounds including benzene, naphthalene, C9-C18 aliphatics, C5-C8 aliphatics, and C9-C22 aromatic hydrocarbon fractions, have also been detected in groundwater samples collected within the surficial aquifer at concentrations exceeding the NCGWQS (**Figure 9**). The extent of petroleum-related compounds is limited to the ZVI soil mixing area. The highest detection of a petroleum-related compound was 50,000 µg/L of aliphatics C5-C8.

Upper Castle Hayne Aquifer

Groundwater contamination in the UCH aquifer has been laterally delineated and extends northwest from former Building 25 to approximately 2,100 feet to the west. The vertical extent of impacts within the UCH aquifer ranges from 25 to approximately 60 feet bgs.

PCE was detected at concentrations up to 98,000 µg/L approximately 450 feet downgradient of former Building 25 (**Figure 5**). TCE, cis-1,2-DCE, and VC are also present in the UCH aquifer. The highest concentrations of TCE (8,420 µg/L) are detected approximately 350 feet northwest of former Building 25 (**Figure 6**), while the highest concentrations of cis-1,2-DCE (47,100 µg/L), and VC (1,520 µg/L) are located vertically below the ZVI soil mixing area (**Figures 7** and **8**, respectively).

A dilute plume of petroleum-related hydrocarbons was detected across a larger area in the UCH aquifer than the surficial aquifer, originating near the former UST tank basin, and extending downgradient (**Figure 9**).

Middle Castle Hayne Aquifer

Groundwater contamination in the MCH aquifer has been laterally delineated and extends from approximately 250 feet downgradient of former Building 25 to approximately 700 feet west. The vertical extent of impacts within the MCH aquifer ranges from 60 to approximately 125 feet bgs. PCE, TCE, cis-1,2-DCE, and VC were the most prevalent contaminants in the MCH aquifer.

PCE was detected at concentrations up to 98,100 µg/L in the MCH aquifer located northwest of Former Building 25 and the ZVI soil mixing area (**Figure 5**). The TCE and cis-1,2-DCE plumes generally match the PCE footprint (**Figures 6** and **7**) with maximum concentrations of 2,340 µg/L and 8,970 µg/L, respectively. The extent of VC is significantly smaller than the other chlorinated compounds in the MCH aquifer (**Figure 8**) and the maximum concentration was 1,910 µg/L.

Lower Castle Hayne Aquifer

Groundwater impacts in the LCH aquifer are located approximately 400 feet northwest of former Building 25 and span approximately 650 feet northeast-southwest. The vertical extent of impacts within the LCH aquifer ranges from 125 to approximately 180 feet bgs. Similar to the MCH aquifer, PCE, TCE, cis-1,2-DCE, and VC were the most prevalent compounds in the LCH aquifer.

The footprints of PCE and daughter products are similar in the LCH aquifer. PCE is present with concentrations up to 1,840 µg/L. Maximum TCE, cis-1,2-DCE, and VC concentrations are 1,100 µg/L, 7,380 µg/L, and 5,890 µg/L, respectively.

2.4.3 Dense Non-Aqueous Phase Liquid

DNAPL has been observed within the surficial aquifer to the south of the ZVI soil mixing area in Zone 1. Additionally, groundwater concentrations of PCE in the UCH and MCH aquifers have been observed in Zone 2 in excess of 1 percent of the solubility of PCE (approximately 200 milligrams per liter [mg/L] [Kueper et al., 2014]) with concentrations of 98 mg/L and 98.1 mg/L, respectively, which suggests the presence of DNAPL. Areas with suspected DNAPL are shown on **Figure 5** where concentrations in groundwater samples exceed 2 mg/L (2,000 µg/L).

DNAPL and site media containing PCE at concentrations indicative of DNAPL are both toxic and serve as a reservoir of source material for dissolved phase groundwater contamination. These source materials are considered PTW.

2.4.4 Soil Gas and Indoor Air

Soil gas samples were collected at Site 88 where buildings were located within 100 feet laterally of surficial aquifer groundwater and/or vadose zone soil containing VOCs above screening levels. Samples were collected near and/or beneath Buildings 3, 3B, 37, 43, 133, and HP57 (**Figure 10**). Based on the exceedance of Base-specific soil gas screening levels, each building was identified for indoor air sampling. All exceedances of soil gas VISLs are within the footprint of the groundwater plume (**Figure 10**). The following is a summary by building of results compared to soil gas and indoor air screening levels[B]:

- Building 3 - PCE and TCE exceeded the screening levels in soil gas with the highest concentrations reported on the north side of the building. In indoor air, only PCE exceeded the indoor air screening level in the sample collected in the northern portion of the building.
- Building 3B – PCE and TCE exceeded screening levels in soil gas with the highest concentrations reported on the east side of the building nearest to the industrial sewer line identified as an additional PCE conduit during the RI. PCE and TCE exceeded indoor air screening levels in an initial indoor air sample that was collected, as well as PCE at three locations during follow-up sampling with the maximum concentration located in the central area of the building.
- Building 37 – PCE and TCE exceeded screening levels in exterior and subslab soil gas. In exterior soil gas, the highest concentrations were reported to the west of the building. In subslab soil gas, the highest concentrations were reported in the central portion of the building. PCE exceeded the indoor air screening level in one sample collected in the central portion of the building.
- Building 43 – PCE, TCE, and VC exceeded screening levels in exterior and subslab soil gas. In indoor air, PCE, chloroform, and 1,4-dichlorobenzene exceeded screening levels throughout the building.
- Building 133 – There were no exceedances of current screening levels in soil gas at Building 133. In indoor air, chloroform exceeded the indoor air screening level, but it was attributed to being present in potable water and was not considered a site-related contaminant.
- Building HP57 – In soil gas, TCE exceeded screening levels during initial sampling but did not exceed during subsequent events. In indoor air, PCE, TCE, 1,4-dichlorobenzene, benzene, carbon tetrachloride, and chloroform exceeded screening levels; the source of PCE and TCE was determined to be an uncapped sewer pipe.

A VIMS was installed in Building 3B and sewer ventilation system was installed in Building HP57 to mitigate the human health risks in indoor air (see **Section 2.7.1**). Although VI was not a significant pathway of concern, there was a potential for the VI pathway to become significant at Buildings 3, 37, and 43 in the future; therefore, the Base elected to install a VIMS in Buildings 3, 37, and 43, as a precautionary measure. No site-related COCs were identified in Building 133 indoor air; therefore, a VIMS was not installed.

Based on VIMS monitoring to date, there are no longer COCs detected in indoor air at concentrations above screening levels attributable to VI.

2.5 Fate and Transport

Contamination at the site originated at former Building 25 and is likely a result of dry cleaning fluid releases associated with the dry-cleaning operations conducted within the building, chemical storage in the AST and USTs

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[B] Soil gas data are screened against current site-specific USEPA Residential soil gas VISL (Target Cancer Risk = 1×10^{-5} and Hazard Quotient [HQ] = 1) (**Figure 10**). Indoor air data are screened against the USEPA Regional Screening Levels (RSLs) current at the time of the investigation. Where a complete VI pathway was identified, it was mitigated by VIMS. There are no longer indoor air exceedances attributable to VI.

that may have spilled or leaked, and a compromised sewer line which may have allowed DNAPL migration into soil and groundwater. This section details the primary fate and transport pathways of contaminants across the site.

2.5.1 DNAPL Migration and Releases from Soil

Contaminants in surface and subsurface soil can migrate into groundwater when precipitation percolates through unsaturated soil and dissolves contaminants from the soil into the underlying aquifer. VOCs in soil can migrate to the atmosphere when volatilized into soil gas in the unsaturated zone.

Soils in the vicinity of former Building 25 that were impacted by the PCE releases were treated by the ZVI soil mixing NTCRA. PCE concentrations in soil were reduced by more than 99 percent within one year of mixing. Additional soil samples were collected in 2015, which indicated that attenuation of COCs is ongoing. Further, contaminant mobility from soil was reduced through the addition of bentonite to the soil mix resulting in a reduced hydraulic conductivity of 50 to 400 times within the treated area. The area is covered with an asphalt parking lot; therefore, infiltration into the area is minimized.

Soils in the vicinity of the storm and wastewater sewer lines to the northwest contain elevated concentrations of PCE in the saturated zone (collected from below the water table). This supports the assumption that DNAPL migrated via the subsurface conveyance system located approximately 3 to 8 feet bgs, within the smear zone of the water table (0 to 5 feet bgs) and was released through cracks or breaks in the piping. The DNAPL observed in this area, as described in **Section 2.4.3**, may be a continuing source of PCE into groundwater (**Figure 5**).

2.5.2 Migration in Groundwater

Once in groundwater, the VOCs are transported through advection and dispersion both vertically and horizontally through the surficial and Castle Hayne aquifers.

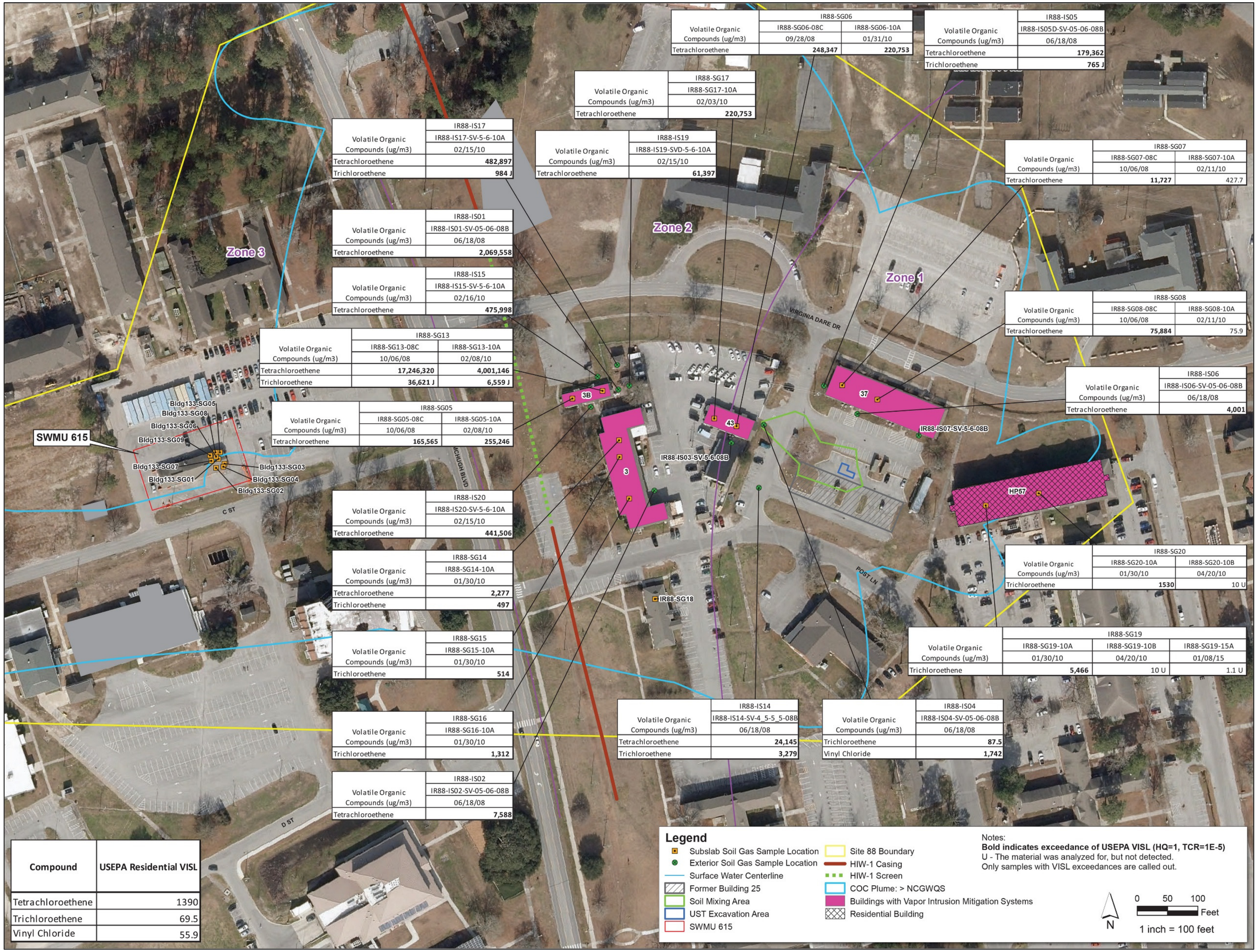
Based upon the groundwater flow directions and contaminant plume concentrations, migration of contaminants is westward toward the New River. The dissolved-phase groundwater contaminant plume emanates from the north side of former Building 25 and follows the route of the subsurface sewer system to the north and northwest, where DNAPL leaked from faulty piping. After release from the sewer pipes, the PCE was transported in the various aquifer zones and spread to its current position.

Vertical migration is occurring as evidenced by the presence of VOCs in wells screened in the UCH, MCH, and LCH aquifer zones and downward vertical potentials have been measured between the different aquifer zones. Vertical migration at former Building 25 is limited by the Belgrade Formation (UCH confining unit) which is intact at that location.

Predictive modeling using BIOCHLOR, supported by empirical data, was conducted as part of the FS to estimate the time for concentrations of contaminants, particularly PCE and daughter products, in groundwater to achieve NCGWQS via natural attenuation (NA) and the potential for contaminants to migrate as far as the New River. For the purposes of predicting downgradient concentrations, the model assumed that active treatment activities will reduce concentrations of PCE to 700 µg/L (1,000 times the NCGWQS). Additionally, the model was run with an assumed 90 percent reduction of daughter product concentrations, as measured in 2014, following completion of the RA. According to the model, the concentrations of PCE, TCE, cis-1,2-DCE, and VC following the RA would require approximately 210, 171, 128, and 259 years, respectively, to attenuate below their respective NCGWQS. In comparison, if PCE concentrations remain untreated, and little to no attenuation occurs, contaminants could migrate downgradient and discharge at the New River at concentrations above NCGWQS and North Carolina Surface Water Quality Standards within approximately 30 years[C].

[C] BIOCHLOR is a screening-level analytical model that employs simplifying assumptions about hydrogeologic and biological processes. Because actual subsurface conditions are generally complex, the model can provide only approximate estimates of remediation timeframes.

FIGURE 10
VISL Exceedances in Soil Gas



Compound	USEPA Residential VISL
Tetrachloroethene	1390
Trichloroethene	69.5
Vinyl Chloride	55.9

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2.5.3 Vapor Intrusion

VI occurs when VOCs volatilize from shallow groundwater or soil into soil gas, and migrate into overlying buildings through cracks in basements, foundations, or other openings of a building, such as sewer lines. When VOCs are able to travel from the subsurface to indoor air within a building, the VI pathway is considered complete. VIMS were installed in Buildings 3, 3B, 37, and 43 and a sewer ventilation system was installed in the sewer line that connects to Building HP57. As a result of operating the VIMS and sewer ventilation system, the VI pathway is incomplete.

2.6 Current and Potential Future Land and Water Uses

Land use at Site 88 is currently industrial and residential (barracks). The area within the site is mostly used for administrative and office buildings. Barracks are present within Zone 1, upgradient of the former dry-cleaning operations. There are no current plans for land use to change in the future; however, buildings may be demolished to facilitate future construction, if needed.

Potable water for MCB Camp Lejeune and the surrounding residential area is provided by public water supply wells that pump groundwater from the Castle Hayne aquifer. Groundwater from beneath Site 88 is not used as a source of drinking water for MCB Camp Lejeune and there are no active potable water supply wells within a 1-mile radius of Site 88. The closest active water supply well (606) is located 1.75 miles upgradient. However, under North Carolina's classification, the surficial and Castle Hayne aquifers are considered Class GA, a potential source of drinking water. Under the NCP at 40 CFR §300.430(a)(1)(iii)(F), USEPA expects to return usable ground waters to their beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site.

2.7 Summary of Site Risks

Potential **human health and ecological risks** at Site 88 were evaluated as part of the RI, Basewide VI Evaluation, and FS. **Table 2** and the following subsections briefly summarize the findings of these risk assessments. Surface soil is not a medium of concern because the chemical releases at Site 88 are associated with subsurface media and contaminated surface soil has either been removed, treated during the soil mixing activities, or is covered with clean soil or asphalt. Surface water and sediment are also not media of concern because there is no current pathway to the closest water body.

TABLE 2
Risk Summary

Medium	Human Health Risk	Ecological Risk[a]
Subsurface Soil	Acceptable	Not Applicable
Groundwater	Unacceptable	Acceptable
Soil Gas	Unacceptable	Not Applicable
Indoor Air	Acceptable[b]	Not Applicable

Notes:

[a] Ecological receptors are not exposed to subsurface soil, soil gas, or indoor air. Groundwater was used to identify potential risks for receptors in surface water that could receive groundwater in the future.

[b] Human health risks to current and future receptors are acceptable under current conditions.

2.7.1 Human Health Risk Summary

The human health risk assessment (HHRA) was completed to evaluate the potential impact of COCs on human health resulting from exposure to subsurface soil, groundwater, soil gas, and indoor air via VI at Site 88.

Current receptors and exposure pathways evaluated included the following:

- Industrial worker: Inhalation of indoor air in Buildings 3, 3B, 37, 43, 58, 133, and HP57.
- Adult resident: Inhalation of indoor air in Building HP57.

Potential future receptors and exposure pathways evaluated included the following:

- Adult and child resident: Ingestion of, dermal contact with, and inhalation (adult only) of VOCs from groundwater; inhalation of VOCs in indoor air associated with VI from the surficial aquifer groundwater and soil gas (based on VOC concentrations in respective media) if buildings are constructed within 100 feet of impacted groundwater or soil gas; incidental ingestion of, dermal contact with, and inhalation of VOC and particulate emissions from subsurface soil.
- Construction worker: Dermal contact with and inhalation of volatiles from surficial aquifer groundwater; inhalation of VOCs from soil gas in an excavation pit; incidental ingestion of, dermal contact with, and inhalation of VOC and particulate emissions from subsurface soil.
- Industrial worker: Inhalation of VOCs in indoor air associated with VI if buildings are constructed within 100 feet of impacted groundwater or soil gas; incidental ingestion of, dermal contact with, and inhalation of VOC and particulate emissions from subsurface soil.

Health risks are based on a conservative estimate of the potential cancer risk or the potential to cause other health effects not related to cancer [non-cancer hazard, or hazard index (HI)]. USEPA identifies an acceptable cancer risk range of 1 in 10,000 (10^{-4}) to 1 in 1,000,000 (10^{-6}) and an acceptable non-cancer hazard as an HI that does not exceed 1. The estimates of risk at Site 88 were used to determine if any further actions were required to sufficiently protect human health. The following section provides a summary of the HHRA by media. The CSM (**Figure 3**) depicts the potential risk identified at Site 88, including the exposure media, exposure routes, and potential human health receptors. **Tables 3** through **6** summarize the potential human health risks.

Subsurface Soil

There were no potential unacceptable risks to industrial or construction workers from exposure to contaminants in soil.

Potential unacceptable risk to future residents was identified associated with inhalation and particulate emissions of aliphatics C9-C12 in subsurface soil within the source area (**Table 3**). However, as discussed in **Sections 2.4.1** and **2.5.1**, soil samples evaluated in the risk assessment were **collected within the soil mixing treatment area**, where ongoing treatment is expected to continue. Additionally, leaching to groundwater is minimized by the reduced hydraulic conductivity from the soil mixing NTCRA. Further, the greatest concentrations of contaminants in soil were observed below the water table or within the smear zone and would likely be treated by the groundwater remedy. Therefore, based on the above lines of evidence, potential unacceptable risks associated with exposure to subsurface soil were not retained and there are no COCs requiring a response action.

Groundwater

The following potential unacceptable risks associated with contaminants in groundwater were identified (**Table 4**):

- Future Residents (potable use):
  - PCE, TCE, cis-1,2-DCE, and VC in the surficial, UCH, MCH, and LCH aquifers.
  - Aliphatics C5-C8, aliphatics C9-C12, aliphatics C9-C18, aromatics C11-C22, and aromatics C9-C10 in the surficial aquifer.
  - Aliphatics C5-C8, aliphatics C9-C12, and aromatics C9-C10 in the UCH aquifer.
- Future Residents (in indoor air via the VI pathway): PCE, TCE, and VC in the surficial aquifer.

- Future Construction Worker (dermal exposure and inhalation of vapors in an excavation): cis-1,2-DCE, VC, aliphatics C9-C12, and aliphatics C9-C18 in the surficial aquifer.
- Future Industrial Worker (in indoor air via the VI pathway): PCE, TCE, and VC in the surficial aquifer.

It should be noted that there is uncertainty associated with the aliphatic and aromatic toxicity values used for the risk calculations, particularly when the carbon range was large or overlapped. In these instances, the most conservative toxicity value was used. Many of the VOCs and one of the semi-volatile organic compounds that comprise total petroleum hydrocarbons were also analyzed in the groundwater samples and evaluated in the risk assessment. Additionally, the maximum detected concentrations were used as the exposure point concentrations for aliphatics C5-C8, aliphatics C9-C12, aliphatics C9-C18, aromatics C11-C22, and aromatics C9-C10, and were all from one sample location collected in support of the 2011 Phase I LSA from IR88-MW31, which is located within the ZVI soil mixing area near the former UST tank basin. Additional samples collected in 2014 and 2015 within the same vicinity did not yield unacceptable risks. Furthermore, on-going ZVI polishing within the soil mixing area has been observed over time and since the hydraulic conductivity was significantly reduced by the soil mixing NTCRA, the migration of COCs in groundwater outside of the soil mixing treatment area is mitigated. Finally, the selected groundwater treatment remedy will treat any residual impacts from aliphatics/aromatic compounds in groundwater outside of the soil mixing area since these compounds are comingled within and do not extend beyond the chlorinated VOC plume targeted for active treatment. Therefore, based on the above lines of evidence, there are no unacceptable risks associated with aliphatics C5-C8, aliphatics C9-C12, aliphatics C9-C18, aromatics C11-C22, and aromatics C9-C10 in groundwater.

The COCs requiring a response action in groundwater are: PCE, TCE, cis-1,2-DCE, and VC.

Soil Gas

The following potential unacceptable risks associated with contaminants in soil gas were identified (**Table 5**):

- Future Residents: PCE, TCE, VC, and methylene chloride.
- Future Construction Worker: PCE, TCE, VC, methylene chloride, and benzene.
- Future Industrial Worker: PCE and TCE.

For future residents and industrial workers, unacceptable risks are based on a potential VI pathway that is currently not complete. For future construction workers, unacceptable risk is based on direct exposure to soil gas during potential future construction.

Methylene chloride was not retained as a COC because it is a byproduct of the drinking water disinfection process. Benzene was not retained as a COC because the maximum concentration is less than the adjusted USEPA VISLs for a Target Cancer Risk of 1.0×10^{-4} and HQ of 1.0.

The COCs requiring a response action in soil gas are: PCE, TCE, and VC.

Indoor Air

The following potential unacceptable risks associated with contaminants in indoor air were identified (**Table 6**):

- Industrial Worker – Building 3B: PCE.
- Industrial Worker – Building HP57: TCE.

Although indoor air data evaluated in the HHRA indicated there was a potential unacceptable risk to current barrack residents from TCE in indoor air at Building HP57, vents and p-traps were repaired within the building and a sewer ventilation system was installed to mitigate the sewer preferential pathway. Subsequent monitoring has indicated it is working as planned and there are no unacceptable risks to current residents while the vents, p-traps, and sewer ventilation system are maintained. Additionally, indoor air data evaluated in the HHRA indicated there was a potential unacceptable risk to current industrial workers from PCE in indoor air at Building 3B. A VIMS was installed in Building 3B and VIMS were also installed at in Buildings 3, 37, and 43 as a precautionary measure. Subsequent monitoring has indicated they are working as designed and there are no unacceptable risks to current industrial workers. Building 3 is currently unoccupied following damage from Hurricane Florence in September 2018. As a result, the VIMS is not currently operating. Buildings 3 and 3B are scheduled to be demolished in the near future.

2.7.2 Ecological Risk Summary

A screening-level Ecological Risk Assessment (ERA) was conducted as part of the RI to evaluate potential risks to ecological receptors from exposure to groundwater and soil contamination at the site. Site 88 is in a highly developed area of the Base with little quality ecological habitat because of the predominance of buildings and paved surfaces for roads and parking lots, disconnecting the soil exposure pathway. However, the groundwater-to-surface-water pathway would require consideration if COCs migrate from groundwater into surface water at concentrations that could present a potential unacceptable risk to future ecological receptors.

Risk was estimated by calculating HQs using the concentration of each contaminant in applicable media (groundwater that may discharge into surface water) and dividing by an ecological screening value. Contaminants were retained for further assessment if the HQ was greater than 1 (the concentration exceeded the ecological screening value), the contaminant was detected but did not have an ecological screening value, or the contaminant was not detected but the reporting limit was greater than the ecological screening value. The list of COCs was further refined using a weight-of-evidence approach that considered spatial and temporal distribution of analytical results, the general ecological setting and health of the ecosystems, and food web modeling.

The results indicated that no constituents in groundwater were identified that are expected to cause a significant risk to populations of ecological receptors in nearby surface water.

2.7.3 Basis for Response Action

It is the current judgment of the Navy, MCB Camp Lejeune, and USEPA, in concurrence with NCDEQ, that the Selected Remedy identified in this ROD is necessary to protect public health or welfare or the environment from actual or threatened releases of hazardous substances into the environment.

Based on the HHRA, exposure to COCs at Site 88 poses an unacceptable future risk to human health via potable use of groundwater, dermal exposure to groundwater and inhalation of vapors from groundwater and soil gas in an excavation, and in indoor air via the VI pathway. In addition, under North Carolina's groundwater classification, the surficial and Castle Hayne aquifers are considered Class GA, a potential source of drinking water. NCDEQ identified NCGWQS as a 'relevant and appropriate' requirement for groundwater remediation. Although benzene and naphthalene in groundwater do not contribute to unacceptable future risk, each constituent is present at concentrations exceeding NCGWQS, and therefore are included as COCs.

COCs requiring a response action in groundwater are summarized in **Table 7**. It is conservatively assumed that the extent of groundwater COCs requiring a response action (see Section 2.11, **Figure 11**) incorporates the area requiring a response for risks associated with dermal exposure and inhalalation of soil gas. Treatment of PTW and groundwater is expected to reduce groundwater concentrations below levels that result in VI pathways of concern (**Table 8**). In the interim, continued operation and monitoring of the VIMS at Building 3B and the sewer ventilation system at Building HP57 will continue to mitigate the VI pathway. In addition, as a precautionary measure, continued operation and monitoring of VIMS at Buildings 3, 37, and 43 will mitigate the potential for the VI pathway to become significant in the future.

Although there are no soil COCs, it is noted that PCE, aliphatics C9-C18, aromatics C9-C10, and aromatics C11-C22 remain in soil within the ZVI soil mixing area at concentrations exceeding soil-to-groundwater MSCCs, suggesting that contaminated soil could serve as a continuing source to groundwater. However, there is evidence of ongoing treatment occurring within the ZVI soil mixing area that will continue to benefit groundwater remediation; therefore, until residual treatment is complete, disturbance of the soil mixing area should be limited.

TABLE 3
Summary of Human Health Risks in Subsurface Soil

Receptor	Media	Pathway	Chemical of Potential Concern	EPC	EPC Statistic	RME Non-Cancer HI - Adult/Child	CTE Non-Cancer HI - Adult/Child	RME Cancer Risk	CTE Cancer Risk	Non-Cancer Toxicity Factor - RfD/RfC[a]	Cancer Toxicity Factor - Cancer Slope Factor[a]
Potential Future Receptors											
Industrial worker	Subsurface Soil	Ingestion	PCE	8.3 mg/kg	Bootstrap UCL	0.001 / N/A	N/A	4.8x10^{-9}	N/A	6.0x10^{-3} mg/kg-day	2.1x10^{-3} mg/kg/day
			Aliphatics C9-C12	140 mg/kg	Maximum	0.011 / N/A	N/A	N/A	N/A	1.0x10^{-2} mg/kg-day	N/A
			Aliphatics C9-C18	57 mg/kg	Maximum	0.004 / N/A	N/A	N/A	N/A	1.0x10^{-2} mg/kg-day	N/A
			Aromatics C9-C10	130 mg/kg	Maximum	0.025 / N/A	N/A	N/A	N/A	4.0x10^{-3} mg/kg-day	N/A
		Dermal	PCE	8.3 mg/kg	Bootstrap UCL	0.000 / N/A	N/A	6.1x10^{-10}	N/A	6.0x10^{-3} mg/kg-day	2.1x10^{-3} mg/kg/day
			Aliphatics C9-C12	140 mg/kg	Maximum	0.005 / N/A	N/A	N/A	N/A	1.0x10^{-2} mg/kg-day	N/A
			Aliphatics C9-C18	57 mg/kg	Maximum	0.002 / N/A	N/A	N/A	N/A	1.0x10^{-2} mg/kg-day	N/A
			Aromatics C9-C10	130 mg/kg	Maximum	0.011 / N/A	N/A	N/A	N/A	4.0x10^{-3} mg/kg-day	N/A
	Air Emissions from Subsurface Soil	Inhalation	PCE	0.0029 mg/m^3	Bootstrap UCL	0.015 / N/A	N/A	5.6x10^{-8}	N/A	4.0x10^{-2} mg/m^3	2.6x10^{-7} (µg/m^3)$^{-1}$
			Aliphatics C9-C12	0.11 mg/m^3	Maximum	0.226 / N/A	N/A	3.6x10^{-5}	N/A	1.0x10^{-1} mg/m^3	4.5x10^{-6} (µg/m^3)$^{-1}$
			Aliphatics C9-C18	0.044 mg/m^3	Maximum	0.091 / N/A	N/A	1.5x10^{-5}	N/A	1.0x10^{-1} mg/m^3	4.5x10^{-6} (µg/m^3)$^{-1}$
			Aromatics C9-C10	0.002 mg/m^3	Maximum	0.139 / N/A	N/A	N/A	N/A	3.0x10^{-3} mg/m^3	N/A
	Total Subsurface Soil - Industrial Worker					0.530 / N/A	N/A	5.1x10^{-5}	N/A		
Residential	Subsurface Soil	Ingestion	PCE	8.3 mg/kg	Bootstrap UCL	0.002 / 0.018	0.0003 / 0.004	2.5x10^{-8}	5.0x10^{-9}	6.0x10^{-3} mg/kg-day	2.1x10^{-3} mg/kg/day
			Aliphatics C9-C12	140 mg/kg	Maximum	0.017 / 0.179	0.003 / 0.042	N/A	N/A	1.0x10^{-2} mg/kg-day	N/A
			Aliphatics C9-C18	57 mg/kg	Maximum	0.007 / 0.072	0.001 / 0.017	N/A	N/A	1.0x10^{-2} mg/kg-day	N/A
			Aromatics C9-C10	130 mg/kg	Maximum	0.039 / 0.416	0.008 / 0.098	N/A	N/A	4.0x10^{-3} mg/kg-day	N/A
		Dermal	PCE	8.3 mg/kg	Bootstrap UCL	0.0002 / 0.001	0.00003 / 0.0003	2.1x10^{-9}	3.2x10^{-10}	6.0x10^{-3} mg/kg-day	2.1x10^{-3} mg/kg/day
			Aliphatics C9-C12	140 mg/kg	Maximum	0.007 / 0.042	0.001 / 0.008	N/A	N/A	1.0x10^{-2} mg/kg-day	N/A
			Aliphatics C9-C18	57 mg/kg	Maximum	0.003 / 0.017	0.000 / 0.003	N/A	N/A	1.0x10^{-2} mg/kg-day	N/A
			Aromatics C9-C10	130 mg/kg	Maximum	0.016 / 0.099	0.002 / 0.020	N/A	N/A	4.0x10^{-3} mg/kg-day	N/A
	Air Emissions from Subsurface Soil	Inhalation	PCE	0.0029 mg/m^3	Bootstrap UCL	0.070 / 0.070	0.070 / 0.070	2.7x10^{-7}	1.6x10^{-7}	4.0x10^{-2} mg/m^3	2.6x10^{-7} (µg/m^3)$^{-1}$
			Aliphatics C9-C12	0.11 mg/m^3	Maximum	1.055 / 1.055	1.055 / 1.055	1.8x10^{-4}	1.0x10^{-4}	1.0x10^{-1} mg/m^3	4.5x10^{-6} (µg/m^3)$^{-1}$
			Aliphatics C9-C18	0.044 mg/m^3	Maximum	0.426 / 0.426	0.426 / 0.426	7.1x10^{-5}	4.1x10^{-5}	1.0x10^{-1} mg/m^3	4.5x10^{-6} (µg/m^3)$^{-1}$
			Aromatics C9-C10	0.002 mg/m^3	Maximum	0.650 / 0.650	0.650 / 0.650	N/A	N/A	3.0x10^{-3} mg/m^3	N/A
	Total Subsurface Soil - Residential					2.291 / 3.044	2.217 / 2.393	2.5x10^{-4}	1.5x10^{-4}		

TABLE 3

Summary of Human Health Risks in Subsurface Soil

Receptor	Media	Pathway	Chemical of Potential Concern	EPC	EPC Statistic	RME Non-Cancer HI - Adult/Child	CTE Non-Cancer HI - Adult/Child	RME Cancer Risk	CTE Cancer Risk	Non-Cancer Toxicity Factor - RfD/RfC[a]	Cancer Toxicity Factor - Cancer Slope Factor[a]
Construction Worker	Subsurface Soil	Ingestion	PCE	8.3 mg/kg	Bootstrap UCL	0.003 / N/A	N/A	7.1×10^{-10}	N/A	8.0×10^{-3} mg/kg-day	2.1×10^{-3} (mg/kg-day)$^{-1}$
			Aliphatics C9-C12	140 mg/kg	Maximum	0.004 / N/A	N/A	N/A	N/A	1.0×10^{-1} mg/kg-day	N/A
			Aliphatics C9-C18	57 mg/kg	Maximum	0.002 / N/A	N/A	N/A	N/A	1.0×10^{-1} mg/kg-day	N/A
			Aromatics C9-C10	130 mg/kg	Maximum	0.092 / N/A	N/A	N/A	N/A	4.0×10^{-3} mg/kg-day	N/A
		Dermal	PCE	8.3 mg/kg	Bootstrap UCL	0.0003 / N/A	N/A	6.8×10^{-11}	N/A	8.0×10^{-3} mg/kg-day	2.1×10^{-3} (mg/kg-day)$^{-1}$
			Aliphatics C9-C12	140 mg/kg	Maximum	0.001 / N/A	N/A	N/A	N/A	1.0×10^{-1} mg/kg-day	N/A
			Aliphatics C9-C18	57 mg/kg	Maximum	0.001 / N/A	N/A	N/A	N/A	1.0×10^{-1} mg/kg-day	N/A
			Aromatics C9-C10	130 mg/kg	Maximum	0.029 / N/A	N/A	N/A	N/A	4.0×10^{-3} mg/kg-day	N/A
	Air Emissions from Subsurface Soil	Inhalation	PCE	0.0029 mg/m^3	Bootstrap UCL	0.016 / N/A	N/A	2.5×10^{-9}	N/A	4.1×10^{-2} mg/m^3	2.6×10^{-7} (µg/m^3)$^{-1}$
			Aliphatics C9-C12	0.11 mg/m^3	Maximum	0.251 / N/A	N/A	1.6×10^{-6}	N/A	1.0×10^{-1} mg/m^3	4.5×10^{-6} (µg/m^3)$^{-1}$
			Aliphatics C9-C18	0.044 mg/m^3	Maximum	0.101 / N/A	N/A	6.5×10^{-7}	N/A	1.0×10^{-1} mg/m^3	4.5×10^{-6} (µg/m^3)$^{-1}$
			Aromatics C9-C10	0.002 mg/m^3	Maximum	0.0005 / N/A	N/A	N/A	N/A	3.0×10^{-3} mg/m^3	N/A
	Total Subsurface Soil - Construction Worker					0.501 / N/A	N/A	2.3×10^{-6}	N/A		

Notes:

Highlighted - Analytes with an expected lifetime cancer risk (ELCR) greater than 1×10^{-4} and/or analytes with an HI greater than 1.

CTE risk estimates were not calculated for industrial and construction worker scenario because the RME risks were below target risk levels (cumulative HI greater than 1 and ELCR greater than 1×10^{-4})

[a] Sources: Integrated Risk Information System, Health Effects Assessment Summary Tables, Agency for Toxic Substances and Disease Registry Toxicity Profiles, California Environmental Protection Agency, and National Center for Environmental Assessment, current at time HHRA conducted

µg/L = micrograms per liter

µg/m^3 = micrograms per cubic meter

mg/kg = milligrams per kilogram

mg/kg/day = milligram per kilogram per day

CTE = central tendency exposure

EPC = exposure point concentration

HI = hazard index

N/A = not applicable

RfC = reference concentration

RfD = reference dose

RME = reasonable maximum exposure

UCL = upper confidence limit

TABLE 4
Summary of Human Health Risks in Groundwater

Receptor	Media	Pathway	Contaminants of Potential Concern	Exposure Point Concentration (EPC)	EPC Statistic	RME Non-Cancer HI (Adult/Child)	RME Cancer Risk	Non-Cancer Toxicity Factor - RfD/RfC[a]	Cancer Toxicity Factor - Cancer Slope Factor[a]
Potential Future Receptors									
Residential – Adult/Child	Groundwater – Surficial Aquifer	Ingestion	Benzene	68 µg/L	Maximum	0.51 / 0.84	4.8x10^{-5}	4.0x10^{-3} mg/kg-day	5.5x10^{-2} (mg/kg-day)$^{-1}$
			cis-1,2-DCE	5,000 µg/L	Maximum	74.76 / 124	N/A	2.0x10^{-3} mg/kg-day	N/A
			PCE	260 µg/L	95% UCL	1.32 / 2.2	7.1x10^{-6}	6.0x10-3 mg/kg-day	2.1x10^{-3} (mg/kg-day)$^{-1}$
			TCE	31 µg/L	95% UCL	1.84 / 3.06	2.6x10^{-5}	5.0x10^{-4} mg/kg-day	Kidney: 9.3x10^{-3} (mg/kg-day)$^{-1}$
									NHL+Liver: 3.7x10^{-2} (mg/kg-day)$^{-1}$
			VC	1,200 µg/L	Maximum	12.09 / 20	5.5x10^{-2}	3.0x10^{-3} mg/kg-day	7.2x10^{-1} (mg/kg-day)$^{-1}$
			Naphthalene	19 µg/L	Maximum	0.03 / 0.05	N/A	2.0x10^{-2} mg/kg-day	N/A
			Aliphatics C5-C8	910 µg/L	Maximum	N/A / 3.45	N/A	N/A	N/A
			Aliphatics C9-C12	690 µg/L	Maximum	2.07 / 3.45	N/A	1.0x10^{-2} mg/kg-day	N/A
			Aliphatics C9-C18	420 µg/L	Maximum	1.26 / 2.1	N/A	1.0x10^{-2} mg/kg-day	N/A
			Aromatics C11-C22	100 µg/L	Maximum	0.77 / 1.28	N/A	4.0x10^{-3} mg/kg-day	N/A
			Aromatics C9-C10	65 µg/L	Maximum	0.49 / 0.82	N/A	4.0x10^{-3} mg/kg-day	N/A
		Dermal	Benzene	68 µg/L	Maximum	0.08 / 0.11	6.9x10^{-6}	4.0x10^{-3} mg/kg-day	5.5x10^{-2} (mg/kg-day)$^{-1}$
			cis-1,2-DCE	5,000 µg/L	Maximum	9.12 / 14	N/A	2.0x10^{-3} mg/kg-day	N/A
			PCE	260 µg/L	95% UCL	0.76 / 1.15	4.0x10^{-6}	6.0x10-3 mg/kg-day	2.1x10^{-3} (mg/kg-day)$^{-1}$
			TCE	31 µg/L	95% UCL	0.3 / 0.44	7.3x10^{-6}	5.0x10^{-4} mg/kg-day	Kidney: 9.3x10^{-3} (mg/kg-day)$^{-1}$
									NHL+Liver: 3.7x10^{-2} (mg/kg-day)$^{-1}$
			VC	1,200 µg/L	Maximum	0.94 / 1.36	4.4x10^{-3}	3.0x10-3 mg/kg-day	7.2x10^{-1} (mg/kg-day)$^{-1}$
			Naphthalene	19 µg/L	Maximum	0.02 / 0.03	N/A	2.0x10^{-2} mg/kg-day	N/A
			Aliphatics C5-C8	910 µg/L	Maximum	N/A / N/A	N/A	N/A	N/A
			Aliphatics C9-C12	690 µg/L	Maximum	47.78 / 72	N/A	1.0x10^{-2} mg/kg-day	N/A
			Aliphatics C9-C18	420 µg/L	Maximum	29.18 / 44	N/A	1.0x10^{-2} mg/kg-day	N/A
			Aromatics C11-C22	100 µg/L	Maximum	0.76 / 1.14	N/A	4.0x10^{-3} mg/kg-day	N/A
			Aromatics C9-C10	65 µg/L	Maximum	0.48 / 0.72	N/A	4.0x10^{-3} mg/kg-day	N/A
		Inhalation	Benzene	68 µg/L	Maximum	0.26 / N/A	1.7x10^{-5}	3.0x10^{-2} mg/m^{3}	7.8x10^{-6} (µg/m^{3})
			cis-1,2-DCE	5,000 µg/L	Maximum	N/A / N/A	N/A	N/A	N/A
			PCE	260 µg/L	95% UCL	0.55 / N/A	1.6x10^{-6}	4.0x10^{-2} mg/m^{3}	2.6x10^{-7} (µg/m^{3})
			TCE	31 µg/L	95% UCL	1.41 / N/A	3.3x10^{-6}	2.0x10^{-3} mg/m^{3}	4.1x10^{-6} (µg/m^{3})
			VC	1,200 µg/L	Maximum	1.59 / N/A	2.0x10^{-4}	1.0x10^{-1} mg/m^{3}	4.4x10^{-6} (µg/m^{3})
			Naphthalene	19 µg/L	Maximum	0.4 / N/A	1.2x10^{-5}	3.0x10^{-3} mg/m^{3}	3.4x10^{-5} (µg/m^{3})
			Aliphatics C5-C8	910 µg/L	Maximum	0.17 / N/A	5.6x10^{-6}	6.0x10^{-1} mg/m^{3}	1.9x10^{-7} (µg/m^{3})
			Aliphatics C9-C12	690 µg/L	Maximum	0.66 / N/A	8.5x10^{-5}	1.0x10^{-1} mg/m^{3}	4.5x10^{-6} (µg/m^{3})
			Aliphatics C9-C18	420 µg/L	Maximum	0.4 / N/A	5.2x10^{-5}	1.0x10^{-1} mg/m^{3}	4.5x10^{-6} (µg/m^{3})
			Aromatics C11-C22	100 µg/L	Maximum	2.14 / N/A	N/A	3.0x10^{-3} mg/m^{3}	N/A
			Aromatics C9-C10	65 µg/L	Maximum	1.36 / N/A	N/A	3.0x10^{-3} mg/m^{3}	N/A
		Total Surficial Aquifer				193.5 / 296.2	6.0x10^{-2}		

TABLE 4
Summary of Human Health Risks in Groundwater

Receptor	Media	Pathway	Contaminants of Potential Concern	Exposure Point Concentration (EPC)	EPC Statistic	RME Non-Cancer HI (Adult/Child)	RME Cancer Risk	Non-Cancer Toxicity Factor - RfD/RfC[a]	Cancer Toxicity Factor - Cancer Slope Factor[a]
Residential – Adult/Child	Groundwater – UCH Aquifer	Ingestion	Benzene	1.4 µg/L	Maximum	0.01 / 0.02	1.0x10^{-6}	4.0x10^{-3} mg/kg-day	5.5x10^{-2} (mg/kg-day)$^{-1}$
			cis-1,2-DCE	14,000 µg/L	95% UCL	202.43 / 337	N/A	2.0x10^{-3} mg/kg-day	N/A
			PCE	33,000 µg/L	95% UCL	164.3 / 273	8.9x10^{-4}	6.0x10^{-3} mg/kg-day	2.1x10^{-3} (mg/kg-day)$^{-1}$
			trans-1,2-Dichloroethene	42 µg/L	95% UCL	0.06 / 0.11	N/A	2.0x10^{-2} mg/kg-day	N/A
			TCE	3,400 µg/L	95% UCL	203.71 / 339	2.9x10^{-3}	5.0x10^{-4} mg/kg-day	Kidney: 9.3x10^{-3} (mg/kg-day)$^{-1}$
									NHL+Liver: 3.7x10^{-2} (mg/kg-day)$^{-1}$
			VC	670 µg/L	95% UCL	6.71 / 11.16	3.1x10^{-2}	3.0x10^{-3} mg/kg-day	7.2x10^{-1} (mg/kg-day)$^{-1}$
			Aliphatics C5-C8	22,000 µg/L	Maximum	N/A / N/A	N/A	N/A	N/A
			Aliphatics C9-C12	10 µg/L	Maximum	0.03 / 0.05	N/A	1.0x10^{-2} mg/kg-day	N/A
			Aromatics C9-C10	57 µg/L	Maximum	0.43 / 0.71	N/A	4.0x10^{-3} mg/kg-day	N/A
		Dermal	Benzene	1.4 µg/L	Maximum	0.001 / 0	1.5x10^{-7}	4.0x10^{-3} mg/kg-day	5.5x10^{-2} (mg/kg-day)$^{-1}$
			cis-1,2-DCE	14,000 µg/L	95% UCL	24.7 / 37.21	N/A	2.0x10^{-3} mg/kg-day	N/A
			PCE	33,000 µg/L	95% UCL	94.9 / 142.96	5.0x10^{-4}	6.0x10^{-3} mg/kg-day	2.1x10^{-3} (mg/kg-day)$^{-1}$
			trans-1,2-Dichloroethene	42 µg/L	95% UCL	0.01 / 0.01	N/A	2.0x10^{-2} mg/kg-day	N/A
			TCE	3,400 µg/L	95% UCL	32.73 / 49.3	4.4x10^{-4}	5.0x10^{-4} mg/kg-day	Kidney: 9.3x10^{-3} (mg/kg-day)$^{-1}$
									NHL+Liver: 3.7x10^{-2} (mg/kg-day)$^{-1}$
			VC	670 µg/L	95% UCL	0.52 / 0.75	2.4x10^{-3}	3.0x10^{-3} mg/kg-day	7.2x10^{-1} (mg/kg-day)$^{-1}$
			Aliphatics C5-C8	22,000 µg/L	Maximum	N/A / N/A	N/A	N/A	N/A
			Aliphatics C9-C12	10 µg/L	Maximum	0.71 / 1.07	N/A	1.0x10^{-2} mg/kg-day	N/A
			Aromatics C9-C10	57 µg/L	Maximum	0.42 / 0.63	N/A	4.0x10^{-3} mg/kg-day	N/A
		Inhalation	Benzene	1.4 µg/L	Maximum	0.005 / N/A	3.7x10^{-7}	3.0x10^{-2} mg/kg-day	7.8x10^{-6} (µg/m^3)
			cis-1,2-DCE	14,000 µg/L	95% UCL	N/A / N/A	N/A	N/A	N/A
			PCE	33,000 µg/L	95% UCL	68.58 / N/A	2.0x10^{-4}	4.0x10^{-2} mg/m^3	2.6x10^{-7} (µg/m^3)
			trans-1,2-Dichloroethene	42 µg/L		N/A / N/A	N/A	N/A	N/A
			TCE	3,400 µg/L	95% UCL	156.48 / N/A	3.7x10^{-4}	2.0x10^{-3} mg/m^3	4.1x10^{-6} (µg/m^3)
			VC	670 µg/L	95% UCL	0.88 / N/A	1.1x10^{-4}	1.0x10^{-1} mg/m^3	4.4x10^{-6} (µg/m^3)
			Aliphatics C5-C8	22,000 µg/L	Maximum	4.28 / N/A	1.4x10^{-4}	6.0x10^{-1} mg/m^3	1.9x10^{-7} (µg/m^3)
			Aliphatics C9-C12	10 µg/L	Maximum	0.01 / N/A	1.3x10^{-6}	1.0x10^{-1} mg/m^3	4.5x10^{-6} (µg/m^3)
			Aromatics C9-C10	57 µg/L	Maximum	1.18 / N/A	N/A	3.0x10^{-3} mg/kg-day	N/A
		Total UCH Aquifer				963.09 / 1192.98	3.9x10^{-2}		

TABLE 4
Summary of Human Health Risks in Groundwater

Receptor	Media	Pathway	Contaminants of Potential Concern	Exposure Point Concentration (EPC)	EPC Statistic	RME Non-Cancer HI (Adult/Child)	RME Cancer Risk	Non-Cancer Toxicity Factor - RfD/RfC[a]	Cancer Toxicity Factor - Cancer Slope Factor[a]
Residential – Adult/Child	Groundwater – MCH Aquifer	Ingestion	cis-1,2-DCE	25,000 µg/L	95% UCL	37.04 / 62	N/A	2.0x10^{-3} mg/kg-day	N/A
			PCE	40,000 µg/L	95% UCL	200.4 / 333	1.1x10^{-3}	6.0x10^{-3} mg/kg-day	2.1x10^{-3} (mg/kg-day)$^{-1}$
			TCE	1,600 µg/L	95% UCL	94.45 / 157	1.3x10^{-3}	5.0x10^{-4} mg/kg-day	Kidney: 9.3x10^{-3} (mg/kg-day)$^{-1}$
									NHL+Liver: 3.7x10^{-2} (mg/kg-day)$^{-1}$
			VC	140 µg/L	95% UCL	1.37 / 2.28	6.4x10^{-3}	3.0x10^{-3} mg/kg-day	7.2x10^{-1} (mg/kg-day)$^{-1}$
		Dermal	cis-1,2-DCE	25,000 µg/L	95% UCL	4.52 / 6.81	N/A	2.0x10^{-3} mg/kg-day	N/A
			PCE	40,000 µg/L	95% UCL	115.75 / 174.37	6.1x10^{-4}	6.0x10^{-3} mg/kg-day	2.1x10^{-3} (mg/kg-day)$^{-1}$
			TCE	1,600 µg/L	95% UCL	15.17 / 23	2.1x10^{-4}	5.0x10^{-4} mg/kg-day	Kidney: 9.3x10^{-3} (mg/kg-day)$^{-1}$
									NHL+Liver: 3.7x10^{-2} (mg/kg-day)$^{-1}$
			VC	140 µg/L	95% UCL	0.11 / 0.15	5.0x10^{-4}	3.0x10^{-3} mg/kg-day	7.2x10^{-1} (mg/kg-day)$^{-1}$
		Inhalation	cis-1,2-DCE	25,000 µg/L	95% UCL	N/A / N/A	N/A	N/A	N/A
			PCE	40,000 µg/L	95% UCL	83.65 / N/A	2.5x10^{-4}	4.0x10^{-2} mg/m^3	2.6x10^{-7} (µg/m^3)
			TCE	1,600 µg/L	95% UCL	72.55 / N/A	1.7x10^{-4}	2.0x10^{-3} mg/m^3	4.1x10^{-6} (µg/m^3)
			VC	140 µg/L	95% UCL	0.18 / N/A	2.3x10^{-5}	1.0x10^{-1} mg/m^3	4.4x10^{-6} (µg/m^3)
		Total MCH Aquifer				625.19 / 758.61	1.1x10^{-2}		
Residential – Adult/Child	Groundwater – LCH Aquifer	Ingestion	cis-1,2-DCE	1,500 µg/L	Maximum	22.92 / 38.15	N/A	2.0x10^{-3} mg/kg-day	N/A
			PCE	1,500 µg/L	Maximum	7.59 / 12.63	4.1x10^{-5}	6.0x10^{-3} mg/kg-day	2.1x10^{-3} (mg/kg-day)$^{-1}$
			TCE	230 µg/L	95% UCL	13.5 / 22.5	1.9x10^{-4}	5.0x10^{-4} mg/kg-day	Kidney: 9.3x10^{-3} (mg/kg-day)$^{-1}$
									NHL+Liver: 3.7x10^{-2} (mg/kg-day)$^{-1}$
			VC	560 µg/L	95% UCL	5.54 / 9.22	2.6x10^{-2}	3.0x10^{-3} mg/kg-day	7.2x10^{-1} (mg/kg-day)$^{-1}$
		Dermal	cis-1,2-DCE	1,500 µg/L	Maximum	2.8 / 4.21	N/A	2.0x10^{-3} mg/kg-day	N/A
			PCE	1,500 µg/L	Maximum	4.38 / 6.61	2.3x10^{-5}	6.0x10^{-3} mg/kg-day	2.1x10^{-3} (mg/kg-day)$^{-1}$
			TCE	230 µg/L	95% UCL	2.17 / 3.27	2.9x10^{-5}	5.0x10^{-4} mg/kg-day	Kidney: 9.3x10^{-3} (mg/kg-day)$^{-1}$
									NHL+Liver: 3.7x10^{-2} (mg/kg-day)$^{-1}$
			VC	560 µg/L	95% UCL	0.43 / 0.62	2.0x10^{-3}	3.0x10^{-3} mg/kg-day	7.2x10^{-1} (mg/kg-day)$^{-1}$
		Inhalation	cis-1,2-DCE	1,500 µg/L	Maximum	N/A / N/A	N/A	N/A	N/A
			PCE	1,500 µg/L	Maximum	3.17 / N/A	9.4x10^{-6}	4.0x10^{-2} mg/m^3	2.6x10^{-7} (µg/m^3)
			TCE	230 µg/L	95% UCL	10.37 / N/A	2.4x10^{-5}	2.0x10^{-3} mg/m^3	4.1x10^{-6} (µg/m^3)
			VC	560 µg/L	95% UCL	0.73 / N/A	9.2x10^{-5}	1.0x10^{-1} mg/m^3	4.4x10^{-6} (µg/m^3)
		Total LCH Aquifer				73.6 / 97.21	2.82x10^{-2}		
Residential – Adult/Child	Groundwater – Indoor Air (Surficial Aquifer)	Inhalation	Benzene	14 µg/m^3	Maximum[b]	0.45 / 0.45	3.9x10^{-5}	3.0x10^{-2} (mg/m^3)	7.8x10^{-6} (µg/m^3)
			PCE	390 µg/m^3	Maximum[b]	9.28 / 9.28	3.6x10^{-5}	4.0x10^{-2} (mg/m^3)	2.6x10^{-7} (µg/m^3)
			TCE	20 µg/m^3	Maximum[b]	9.61 / 9.61	4.2x10^{-5}	2.0x10^{-3} (mg/m^3)	Kidney: 1.0x10^{-6} (µg/m^3)
					Maximum[b]				NHL+Liver: 3.1x10^{-6} (µg/m^3)
			VC	1,300 µg/m^3	Maximum[b]	12.58 / 12.58	7.8x10^{-3}	1.0x10^{-1} (mg/m^3)	4.4x10^{-6} (µg/m^3)
			Naphthalene	0.31 µg/m^3	Maximum[b]	0.1 / 0.1	3.7x10^{-6}	3.0x10^{-3} (mg/m^3)	3.4x10^{-5} (µg/m^3)
		Total Surficial Aquifer - Groundwater to Indoor Air				32.02 / 32.02	7.88x10^{-3}		

TABLE 4

Summary of Human Health Risks in Groundwater

Receptor	Media	Pathway	Contaminants of Potential Concern	Exposure Point Concentration (EPC)	EPC Statistic	RME Non-Cancer HI (Adult/Child)	RME Cancer Risk	Non-Cancer Toxicity Factor - RfD/RfC[a]	Cancer Toxicity Factor - Cancer Slope Factor[a]
Construction worker	Groundwater – Surficial Aquifer	Dermal	Benzene	68 µg/L	Maximum	0.04 / N/A	3.4x10^{-7}	1.0x10^{-2} mg/kg-day	5.5x10^{-2} (mg/kg-day)$^{-1}$
			cis-1,2-DCE	5000 µg/L	Maximum	1.2 / N/A	N/A	2.0x10^{-2} mg/kg-day	N/A
			PCE	260 µg/L	95% UCL	0.51 / N/A	1.2x10^{-7}	8.0x10^{-3} mg/kg-day	2.1x10^{-3} (mg/kg-day)$^{-1}$
			TCE	31 µg/L	95% UCL	0.32 / N/A	1.1x10^{-7}	5.0x10^{-4} mg/kg-day	4.6x10^{-2} (mg/kg-day)$^{-1}$
			VC	1,200 µg/L	Maximum	1.45 / N/A	4.5x10^{-5}	3.0x10^{-3} mg/kg-day	7.2x10^{-1} (mg/kg-day)$^{-1}$
			Naphthalene	19 µg/L	Maximum	0 / N/A	N/A	6.0x10^{-1} mg/kg-day	N/A
			Aliphatics C5-C8	910 µg/L	Maximum	0.18 / N/A	N/A	3.0x10^{-1} mg/kg-day	N/A
			Aliphatics C9-C12	690 µg/L	Maximum	2.35 / N/A	N/A	1.0x10^{-1} mg/kg-day	N/A
			Aliphatics C9-C18	420 µg/L	Maximum	1.43 / N/A	N/A	1.0x10^{-1} mg/kg-day	N/A
			Aromatics C11-C22	100 µg/L	Maximum	0.7 / N/A	N/A	4.0x10^{-3} mg/kg-day	N/A
			Aromatics C9-C10	65 µg/L	Maximum	0.45 / N/A	N/A	4.0x10^{-3} mg/kg-day	N/A
		Inhalation	Benzene	68 µg/L	Maximum	0 / N/A	8.0x10^{-9}	8.0x10^{-2} mg/kg-day	7.8x10^{-6} (mg/kg-day)$^{-1}$
			cis-1,2-DCE	5000 µg/L	Maximum	N/A / N/A	N/A	N/A	N/A
			PCE	2600 µg/L	95% UCL	0.01 / N/A	1.5x10^{-9}	4.1x10^{-2} mg/kg-day	2.6x10^{-7} (mg/kg-day)$^{-1}$
			TCE	31 µg/L	95% UCL	0.02 / N/A	2.3x10^{-9}	2.1x10^{-3} mg/kg-day	4.1x10^{-6} (mg/kg-day)$^{-1}$
			VC	1,200 µg/L	Maximum	0.07 / N/A	3.1x10^{-7}	7.7x10^{-2} mg/kg-day	4.4x10^{-6} (mg/kg-day)$^{-1}$
			Naphthalene	19 µg/L	Maximum	0 / N/A	3.8x10^{-9}	3.0x10^{-3} mg/kg-day	3.4x10^{-5} (mg/kg-day)$^{-1}$
			Aliphatics C5-C8	910 µg/L	Maximum	0.07 / N/A	3.9x10^{-7}	2.0x10^{-0} mg/kg-day	1.9x10^{-7} (mg/kg-day)$^{-1}$
			Aliphatics C9-C12	690 µg/L	Maximum	1.46 / N/A	9.4x10^{-6}	1.0x10^{-1} mg/m^{3}	4.5x10^{-6} (mg/kg-day)$^{-1}$
			Aliphatics C9-C18	420 µg/L	Maximum	0.89 / N/A	5.7x10^{-6}	1.0x10^{-1} mg/m^{3}	4.5x10^{-6} (mg/kg-day)$^{-1}$
			Aromatics C11-C22	100 µg/L	Maximum	0 / N/A	N/A	1.0x10^{+1} mg/kg-day	N/A
			Aromatics C9-C10	65 µg/L	Maximum	0 / N/A	N/A	1.0x10^{+1} mg/kg-day	N/A
		Total Surficial Aquifer				9.08 / N/A	6.01x10^{-5}		
Industrial worker (Future)	Groundwater - Indoor Air (Surficial Aquifer)	Inhalation	Benzene	14 µg/m^{3}	Maximum[b]	0.11 / N/A	9.0x10^{-6}	3.0x10^{-2} mg/m^{3}	7.8x10^{-6} (µg/m^{3})
			PCE	390 µg/m^{3}	Maximum[b]	2.21 / N/A	8.2x10^{-6}	4.0x10^{-2} mg/m^{3}	2.6x10^{-7} (µg/m^{3})
			TCE	20 µg/m^{3}	Maximum[b]	2.29 / N/A	6.7x10^{-6}	2.0x10^{-3} mg/m^{3}	4.1x10^{-6} (µg/m^{3})
			VC	1,300 µg/m^{3}	Maximum[b]	3 / N/A	4.7x10^{-4}	1.0x10^{-1} mg/m^{3}	4.4x10^{-6} (µg/m^{3})
		Total Surficial Aquifer Groundwater to Indoor Air				7.61 / N/A	4.94x10^{-4}		

Notes

Highlighted - Analytes with an ELCR greater than 1x10^{-4} and/or analytes with an HI greater than 1.

[a] Sources: Integrated Risk Information System, Health Effects Assessment Summary Tables, Agency for Toxic Substances and Disease Registry Toxicity Profiles, California Environmental Protection Agency, and National Center for Environmental Assessment, current at time HHRA conducted

[b] The maximum detected concentration in groundwater is used to calculate an indoor air concentration. Indoor air concentration calculated using USEPA's Vapor Intrusion Screening Level Calculator, Version 3.5.1, May 2016 RSLs, based on an average groundwater temperature of 23.3 degrees Celsius.

CTE risk estimates were not calculated since the RME risk estimates exceed the target risk levels (cumulative HI greater than 1 and ELCR greater than 1 x 10-4) by at least one order of magnitude for most scenarios

NHL = non-Hodgkin lymphoma

TABLE 5
Summary of Human Health Risks - Soil Gas

Receptor	Media	Pathway	Contaminants of Potential Concern	Exposure Point Concentration (EPC)	EPC Statistic	RME Non-Cancer HI	RME Cancer Risk	Non-Cancer Toxicity Factor - RfD/RfC[a]	Cancer Toxicity Factor - Cancer Slope Factor[a]
Potential Future Receptors									
Residential – Adult/Child	Soil Gas – Indoor Air	Inhalation	1,1,2-TCA	0.023 µg/m³	Maximum[b]	0.11	1.3×10^{-7}	2.0×10^{-4} (mg/m³)	1.6×10^{-5} (µg/m³)
			1,4-dichlorobenzene	18 µg/m³	Maximum[b]	0.02	7.1×10^{-5}	8.0×10^{-1} (mg/m³)	1.1×10^{-5} (µg/m³)
			Benzene	14 µg/m³	Maximum[b]	0.46	4.0×10^{-5}	3.0×10^{-2} (mg/m³)	7.8×10^{-6} (µg/m³)
			Chloroform	1.8 µg/m³	Maximum[b]	0.02	1.4×10^{-5}	9.8×10^{-2} (mg/m³)	2.3×10^{-5} (µg/m³)
			Methylene Chloride	940 µg/m³	Maximum[b]	1.5	9.3×10^{-6}	6.0×10^{-1} (mg/m³)	1.0×10^{-8} (µg/m³)
			PCE	510,000 µg/m³	Maximum[b]	12192.2	4.6×10^{-2}	4.0×10^{-2} (mg/m³)	2.6×10^{-7} (µg/m³)
			TCE	1,100 µg/m³	Maximum[b]	517.91	2.3×10^{-3}	2.0×10^{-3} (mg/m³)	Kidney: 1.0×10^{-6} (µg/m³)
									NHL+Liver: 3.1×10^{-6} (µg/m³)
			VC	51 µg/m³	Maximum[b]	0.49	3.1×10^{-4}	1.0×10^{-1} (mg/m³)	4.4×10^{-6} (µg/m³)
		Total Soil Gas to Indoor Air				12712.6	4.9×10^{-2}		
Construction worker	Soil Gas – Air in Excavation Pit	Inhalation	1,4-dichlorobenzene	600 µg/m³	Maximum	0.11	2.2×10^{-5}	1.2×10^{-0} mg/m³	1.1×10^{-5} (µg/m³)
			Benzene	480 µg/m³	Maximum	1.37	1.2×10^{-5}	8.0×10^{-2} mg/m³	7.8×10^{-6} (µg/m³)
			Chloroform	59 µg/m³	Maximum	0.05	4.4×10^{-6}	2.4×10^{-1} mg/m³	2.3×10^{-5} (µg/m³)
			Methylene Chloride	31,000 µg/m³	Maximum	6.85	1.0×10^{-6}	1.0×10^{-0} mg/m³	1.0×10^{-8} (µg/m³)
			o-Xylene	96 µg/m³	Maximum	0.05	N/A	4.0×10^{-1} mg/m³	N/A
			PCE	17,000,000 µg/m³	Maximum	95124	1.4×10^{-2}	4.1×10^{-2} mg/m³	2.6×10^{-7} (µg/m³)
			TCE	36,000 µg/m³	Maximum	3823	4.8×10^{-4}	2.1×10^{-3} mg/m³	4.1×10^{-6} (µg/m³)
			trichlorofluoromethane	1,000 µg/m³	Maximum	0.23	N/A	1.0×10^{-0} mg/m³	N/A
			VC	1,700 µg/m³	Maximum	5.1	2.5×10^{-5}	7.7×10^{-2} mg/m³	4.4×10^{-6} (µg/m³)
			Naphthalene	2.1 µg/m³	Maximum	0.16	2.4×10^{-7}	3.0×10^{-3} mg/m³	3.4×10^{-5} (µg/m³)
		Total Soil Gas in Excavation				98960.92	1.41×10^{-2}		
Industrial worker (Future)	Soil Gas – Indoor Air	Inhalation	1,4-dichlorobenzene	18 µg/m³	Maximum[b]	0.01	1.6×10^{-5}	8.0×10^{-1} mg/m³	1.1×10^{-5} (µg/m³)
			Benzene	14 µg/m³	Maximum[b]	0.11	9.1×10^{-6}	3.0×10^{-2} mg/m³	7.8×10^{-6} (µg/m³)
			Chloroform	1.8 µg/m³	Maximum[b]	0	3.3×10^{-6}	9.8×10^{-2} mg/m³	2.3×10^{-5} (µg/m³)
			Methylene Chloride	940 µg/m³	Maximum[b]	0.36	7.6×10^{-7}	6.0×10^{-1} mg/m³	1.0×10^{-8} (µg/m³)
			PCE	510,000 µg/m³	Maximum[b]	2902.91	1.1×10^{-2}	4.0×10^{-2} mg/m³	2.6×10^{-7} (µg/m³)
			TCE	1,100 µg/m³	Maximum[b]	123.31	3.6×10^{-4}	2.0×10^{-3} mg/m³	4.1×10^{-6} (µg/m³)
			VC	51 µg/m³	Maximum[b]	0.12	1.8×10^{-5}	1.0×10^{-1} mg/m³	4.4×10^{-6} (µg/m³)
		Total Soil Gas - Indoor Air				3026.82	1.14×10^{-2}		

Notes

Highlighted - Analytes with an ELCR greater than 1×10^{-4} and/or analytes with an HI greater than 1.

µg/L = micrograms per liter

µg/m³ = micrograms per cubic meter

[a] Sources: Integrated Risk Information System, Health Effects Assessment Summary Tables, Agency for Toxic Substances and Disease Registry Toxicity Profiles, California Environmental Protection Agency, and National Center for Environmental Assessment, current at time HHRA conducted

[b] The maximum detected concentration in soil gas is used to calculate an indoor air concentration using USEPA's Vapor Intrusion Screening Level Calculator.

CTE risk estimates were not calculated since the RME risk estimates exceed the target risk levels (cumulative HI greater than 1 and ELCR greater than 1×10^{-4}) by at least one order of magnitude for most scenarios

TABLE 6
Summary of Human Health Risks in Indoor Air

Receptor	Media	Pathway	Chemicals of Potential Concern	EPC	EPC Statistic	RME Non-Cancer HI	RME Cancer Risk	Non-Cancer Toxicity Factor - RfD/RfC[a]	Cancer Toxicity Factor - Cancer Slope Factor[a]
Current Receptors									
Industrial worker	Indoor Air	Inhalation – Bldg 3	None[b]	N/A	N/A	N/A	N/A	N/A	N/A
		Inhalation – Bldg 3B	PCE	490 µg/m^3	Maximum	2.8	1.0x10^{-5}	4.0x10^{-2} mg/m^3	2.6x10^{-7} (µg/m^3)$^{-1}$
			TCE	6.4 µg/m^3	Maximum	0.74	2.2x10^{-6}	2.0x10^{-3} mg/m^3	4.1x10^{-6} (µg/m^3)$^{-1}$
			Total Inhalation Building 3B			3.5	1.5x10^{-5}		
		Inhalation – Bldg 37	None[b]	N/A	N/A	N/A	N/A	N/A	N/A
		Inhalation – Bldg 43	Chloroform	1.8 µg/m^3	Maximum	0.0041	3.3x10^{-6}	9.8x10^{-2} mg/m^3	2.3x10^{-5} (µg/m^3)$^{-1}$
			PCE	52 µg/m^3	Maximum	0.29	1.1x10^{-6}	4.0x10^{-2} mg/m^3	2.6x10^{-7} (µg/m^3)$^{-1}$
			Total Inhalation Building 43			0.29	4.4x10^{-6}		
		Inhalation – Bldg 58	None[b]	N/A	N/A	N/A	N/A	N/A	N/A
		Inhalation – Bldg 133	Chloroform	0.68 µg/m^3	Maximum	0.0016	1.3x10^{-6}	9.8x10^{-2} mg/m^3	2.3x10^{-5} (µg/m^3)$^{-1}$
		Inhalation - Bldg HP57	Chloroform	3.8 µg/m^3	Maximum	0.0089	7.1x10^{-6}	9.8x10^{-2} mg/m^3	2.3x10^{-5} (µg/m^3)$^{-1}$
			TCE	4.4 µg/m^3	Maximum	0.5	1.5x10^{-6}	2.0x10^{-3} mg/m^3	4.1x10^{-6} (µg/m^3)$^{-1}$
			Total Inhalation Building HP57			0.51	8.6x10^{-6}		
Residential - Adult	Indoor Air	Inhalation - Bldg HP57	Chloroform	3.8 µg/m^3	Maximum	0.037	4.8x10^{-76}	9.8x10^{-2} mg/m^3	2.3x10^{-5} (µg/m^3)$^{-1}$
			Ethylbenzene	2.4 µg/m^3	Maximum	0.0023	3.3x10^{-7}	1.0 mg/m^3	2.5x10^{-6} (µg/m^3)$^{-1}$
			TCE	4.4 µg/m^3	Maximum	2.1	9.8x10^{-7}	2.0x10^{-3} mg/m^3	4.1x10^{-6} (µg/m^3)$^{-1}$
			Total Inhalation Building HP57			2.1	6.1x10^{-6}		

Notes

Highlighted - Analytes with an ELCR greater than 1x10^{-4} and/or analytes with an HI greater than 1.

[a] Sources: Integrated Risk Information System, Health Effects Assessment Summary Tables, Agency for Toxic Substances and Disease Registry Toxicity Profiles, California Environmental Protection Agency, and National Center for Environmental Assessment, current at time HHRA conducted

[b] No constituents exceeded screening levels

µg/m^3 = micrograms per cubic meter

mg/m^3 = milligrams per cubic meter

TABLE 7

Groundwater COCs Requiring a Response Action

Groundwater COCs	Detection Rate	Maximum Concentration (µg/L)			NCGWQS/MCL[a] (µg/L)	VISLs[b] (µg/L)
		Zone 1	Zone 2	Zone 3		
Benzene	8/137	14.1	Not detected	Not detected	1	138
Naphthalene	3/126	7.2 J	Not detected	Not detected	6	174
PCE	75/137	16,000	271,000	3,150	0.7	57.6
TCE	77/137	5,760	2,670	574	3	5.18
cis-1,2-DCE	87/137	112,000	653	138	70	--
VC	34/137	7,870	923	10.5	0.03	14.7

Notes:

[a] Value shown is the more conservative value of the two standards.

[b] Value shown is based on the February 2019 USEPA Vapor Intrusion Screening Level Calculator for a Target Cancer Risk of 1.0×10^{-4} and HQ of 1.0 for a residential use scenario. PCE, TCE, benzene, and naphthalene values are based on an HQ of 1.0 and vinyl chloride is based on a target cancer risk of 1.0×10^{-4}. The upper end of the risk range was selected for vinyl chloride because it was detected in sub-slab soil gas but not in indoor air indicating the pathway into indoor air is not complete.

MCL = Maximum Contaminant Level

TABLE 8

VI Pathways of Concern

COCs	Soil Gas		
	Detection Rate[a]	Maximum Concentration ($\mu g/m^3$)	VISLs[b] ($\mu g/m^3$)
PCE	39/42	17,000,000 (Under Building 3B)	1,390
TCE	22/42	36,000 J (Under Building 3B)	69.5
VC	2/39	1,700 (Near Building 43)	559

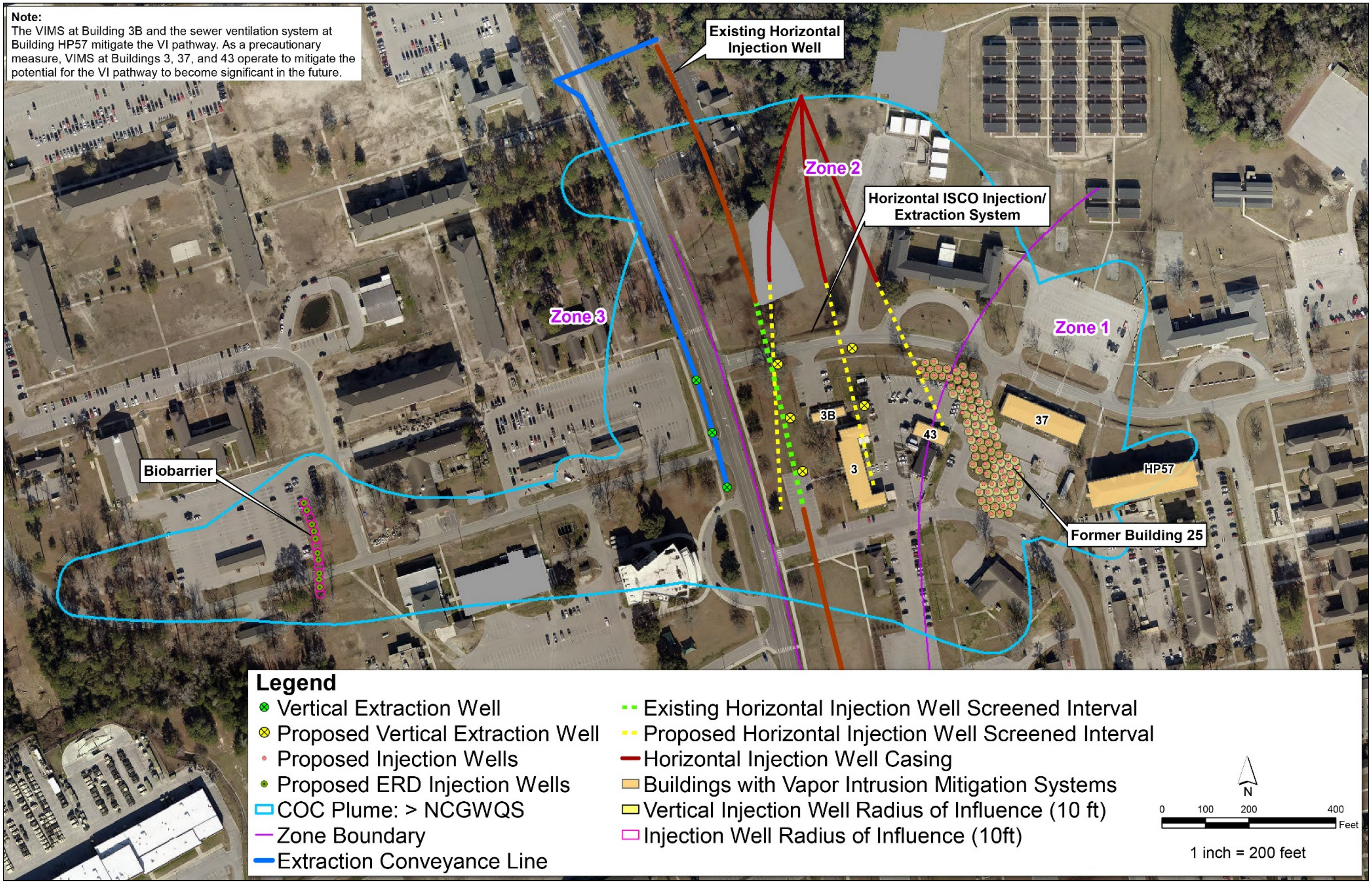
Notes:

[a] Detection rate from samples collected in and adjacent to Buildings 3, 3B, 37, 43, 58, 133, and HP57.

[b] Value shown is based on the February 2019 USEPA Vapor Intrusion Screening Level Calculator for a Target Cancer Risk of 1.0×10^{-4} and HQ of 1.0 for a residential use scenario. PCE and TCE values are based on an HQ of 1.0, and vinyl chloride is based on a target cancer risk of 1.0×10^{-4}. The upper end of the risk range was selected for vinyl chloride because it was detected in sub-slab soil gas but not in indoor air indicating the pathway into indoor air is not complete.

J = Analyte present, value may or may not be accurate or precise

FIGURE 11
Selected Remedy Plan View



2.8 Principal Threat Wastes

PTW is source material considered to be highly toxic or highly mobile that generally cannot be reliably contained or would present a significant risk to human health or the environment should they be exposed. Contaminated groundwater generally is not considered to be a source material; however, non-aqueous phase liquids (NAPLs) in groundwater may be viewed as a source material. As described in **Section 2.4.3**, based on the observance of NAPL in Zone 1 during previous investigations, and the concentrations of PCE in Zone 2 groundwater, it is likely that DNAPL is present. PCE DNAPL and groundwater containing PCE at concentrations greater than solubility levels for protection of groundwater are both toxic and highly mobile and serve as a reservoir of source materials for dissolved phase groundwater contamination. Therefore, these source materials are considered PTW.

The NCP establishes an expectation that the USEPA will use treatment to address the principal threats posed by a site whenever practicable [NCP §300.430(a)(1)(iii)(A)]. NAPL is considered PTW under USEPA guidance, and there is an expectation in the NCP to treat such wastes wherever practicable unless USEPA determines that such wastes can be reliably contained.

Active treatment will be implemented where PTW is suspected to be encountered and LUCs will be implemented to prevent exposure while treatment is ongoing. Restoration of an aquifer contaminated with DNAPL in a reasonable timeframe will not be attained unless the DNAPL can be removed. Any accumulated DNAPL will be removed from monitoring or injection wells if encountered; however, complete removal of DNAPLs from the subsurface is often not practicable. Therefore, restoration of the aquifer to beneficial use within a reasonable timeframe may not be achievable.

2.9 Remedial Action Objectives

To be protective of human health and the environment and address potential future risks identified in the HHRA, the **RAOs** identified for Site 88 are as follows:

1. Restore groundwater quality to meet NCDEQ and federal primary drinking water standards based on the classification of the aquifer as a potential source of drinking water (Class GA or Class GSA) under 15A North Carolina Administrative Code 02L.0201.
2. Reduce groundwater contaminant source mass to the maximum extent practicable within a reasonable timeframe to inhibit migration of COCs to the New River.
3. Prevent human ingestion of and contact with groundwater containing COCs at concentrations above NCGWQS or federal maximum contaminant levels (MCLs), whichever is more stringent.
4. Prevent exposure to COCs in groundwater and soil gas during construction, and through the VI pathway that could result in an unacceptable risk to human health.
5. Restrict intrusive activities and prevent residential use near the ZVI soil mixing treatment area.

The cleanup levels for groundwater COCs are based on the more conservative of the NCGWQS, federal MCL, or VISL as presented in **Table 9**. The cleanup levels for soil gas COCs are based on the February 2019 USEPA Vapor Intrusion Screening Level Calculator for a Target Cancer Risk of 1.0×10^{-4} and HQ of 1.0 for a residential use scenario.

TABLE 9
Cleanup Levels

Cleanup Levels		
COC	Groundwater (µg/L)	Soil Gas (µg/m^3)
Benzene	1	Not applicable[1]
Naphthalene	6	Not applicable1
PCE	0.7	1,390
TCE	3	69.5
cis-1,2-DCE	70	Not applicable[1]
VC	0.03	559

[1]Not a soil gas COC

2.10 Description and Comparative Analysis of Remedial Alternatives

2.10.1 Description of Remedial Alternatives

Based on the initial **screening of technologies**, the following remedial alternatives were retained for comparative analysis as follows:

- Zone 1: (1) No action, (2) AS via vertical well, (3) ISCO via vertical well, (4) ERD via vertical wells
- Zone 2: (1) No action, (2) AS via horizontal well, (3) ISCO via horizontal well
- Zone 3: (1) No action, (2) MNA, (3) Biobarrier

The following are a component of each remedial alternative, with the exception of the no-action alternatives:

- LUCs prohibiting the installation of water supply wells and preventing the unauthorized use of or exposure to contaminated groundwater and soil gas, to evaluate the potential for VI before the construction of new buildings or modifications to existing buildings and restricting residential land use and intrusive activities in the vicinity of the ZVI soil mixing area.
- Maintaining the existing VIMS at Building 3B and the sewer ventilation system at Building HP57 to mitigate the human health risks in indoor air. Maintaining the existing VIMS at Building 3, 37, and 43 as a precautionary measure.
- MNA following active treatment to monitor COCs until contaminant concentrations are such that would allow for unlimited use and unrestricted exposure.

The remedial alternatives that were developed and evaluated to address COCs at Site 88 are detailed in the FS. With the exception of the no-action alternatives, all alternatives comply with **Applicable or Relevant, and Appropriate Requirements** (ARARs), have the same RAOs, expected outcomes, and anticipated future land uses. The No Action Alternative does not protect human health and the environment, but is presented as a baseline for comparison purposes. A summary of remedial alternatives is presented by zone in **Tables 10, 11,** and **12**.

TABLE 10
Summary of Remedial Alternatives for Site 88, Zone 1

Alternative	Components	Details	Cost/Timeframe	
1 – No Action	None	None	Total Cost Timeframe	$0 Indefinite
2 – AS/SVE, MNA, LUCs, and VIMS	AS and SVE	Injection of air into the surficial and UCH aquifers to induce volatilization of COCs from groundwater or promote aerobic biodegradation. SVE would be used to collect COCs and control emissions. Conduct groundwater and soil gas performance monitoring during operations.	Capital Cost Operating Cost Total Monitoring Cost Total Present Value Cost Timeframe Active Treatment MNA	$1,510,000 $444,000 $955,000 $2,910,000 5 years 100 years
	MNA	NA processes would be used to address contamination after active treatment is completed. Groundwater monitoring would be conducted to assess progress toward RAOs.		
	LUCs	LUCs to prohibit aquifer use and intrusive activities to prevent exposure to contaminated groundwater and soil gas, require evaluation of VI if future changes in building or land use occur, and to prohibit residential use and restrict intrusive activities in the vicinity of the ZVI soil mixing area.		
	VIMS	Maintain existing VIMS in Buildings 37 and 43, and the sewer ventilation system at Building HP57. Conduct performance monitoring.		
3 – ISCO, MNA, LUCs, and VIMS	ISCO	Injection of permanganate to oxidize COCs in groundwater. Conduct groundwater performance monitoring during operations.	Capital Cost Injection Cost (Year 2) Total Monitoring Cost Total Present Value Cost Timeframe Active Treatment MNA	$1,060,000 $174,000 $944,000 $2,178,000 2 Years 100 years
	MNA	NA processes would be used to address contamination after active treatment is completed. Groundwater monitoring would be conducted to assess progress toward RAOs.		
	LUCs	LUCs to prohibit aquifer use and intrusive activities to prevent exposure to contaminated groundwater and soil gas, require evaluation of VI if future changes in building or land use occur, and to prohibit residential use and restrict intrusive activities in the vicinity of the ZVI soil mixing area.		
	VIMS	Maintain existing VIMS in Buildings 37 and 43, and the sewer ventilation system at Building HP57. Conduct performance monitoring.		
4 – ERD, MNA, LUCs, and VIMS	ERD	Injection of electron source/substrate to facilitate reductive dechlorination of COCs. Conduct groundwater performance monitoring during operations.	Capital Cost Injection Cost (Year 2) Total Monitoring Cost Total Present Value Cost Timeframe Active Treatment MNA	$1,246,000 $324,000 $1,061,000 $2,631,000 4 Years 100 years
	MNA	NA processes would be used to address contamination after active treatment is completed. Groundwater monitoring would be conducted to assess progress toward RAOs.		
	LUCs	LUCs to prohibit aquifer use and intrusive activities to prevent exposure to contaminated groundwater and soil gas, require evaluation of VI if future changes in building or land use occur, and to prohibit residential use and restrict intrusive activities in the vicinity of the ZVI soil mixing area.		
	VIMS	Maintain existing VIMS in Buildings 37 and 43, and the sewer ventilation system at Building HP57. Conduct performance monitoring.		

TABLE 11

Summary of Remedial Alternatives for Site 88, Zone 2

Alternative	Components	Details	Cost/Timeframe	
1 – No Action	None	None	Total Cost Timeframe	$0 Indefinite
2 – AS, MNA, LUCs, and VIMS	AS	Injection of air into the UCH aquifer to volatilize COCs from groundwater or promote aerobic biodegradation. Conduct groundwater and soil gas performance monitoring during operations.	Capital Cost Operating Cost Total Monitoring Cost Total Present Value Cost Timeframe Active Treatment MNA	$ 7,300,000 $ 2,480,000 $ 910,000 $ 10,690,000 5 years 100 years
	MNA	NA processes would be used to address contamination after active treatment is completed. Groundwater monitoring would be conducted to assess progress toward RAOs.		
	LUCs	LUCs to prohibit aquifer use and intrusive activities to prevent exposure to contaminated groundwater and soil gas and require evaluation of VI if future changes in building or land use occur.		
	VIMS	VIMS that are currently installed in Buildings 3 and 3B would be upgraded with blowers capable of providing added protection to counter potential off gassing from AS activities. Install VIMS in neighboring Buildings 67 and 101 and install two sewer ventilation nodes near Buildings 3 and 3B to address increased potential for VI resulting from AS. Conduct performance monitoring.		
3 – ISCO, MNA, LUCs, and VIMS	ISCO	Injection and recirculation of permanganate to oxidize COCs in groundwater. Conduct groundwater performance monitoring during operations.	Capital Cost Injection Cost (Year 2) Total Monitoring Cost Total Present Value Cost Timeframe Active Treatment MNA	$ 9,087,000 $ 4,016,000 $ 855,000 $ 13,958,000 4 years 100 years
	MNA	NA processes would be used to address contamination after active treatment is completed. Groundwater monitoring would be conducted to assess progress toward RAOs.		
	LUCs	LUCs to prohibit aquifer use and intrusive activities to prevent exposure to contaminated groundwater and soil gas and require evaluation of VI if future changes in building or land use occur.		
	VIMS	Maintain existing VIMS in Buildings 3 and 3B. Conduct performance monitoring.		

TABLE 12
Summary of Remedial Alternatives for Site 88, Zone 3

Alternative	Components	Details	Cost/Timeframe	
1 – No Action	None	None	Total Cost Timeframe	$0 Indefinite
2 – MNA and LUCs	MNA	NA processes would be used to address contamination. Groundwater monitoring would be conducted to assess progress toward RAOs.	Capital Cost Total Monitoring Cost Total Present Value Cost Timeframe	$143,000 $400,000 $543,000 100 years
	LUCs	LUCs to prohibit aquifer use and intrusive activities to prevent exposure to contaminated groundwater and require evaluation of VI if future changes in building or land use occur.		
3 – Biobarrier, MNA, and LUCs	Biobarrier	As an added downgradient protectiveness measure, injection of electron source/ substrate to facilitate reductive dechlorination of COCs. Conduct groundwater performance monitoring during operations.	Capital Cost Injection Cost (Years 2-10) Total Monitoring Cost Total Present Value Cost Timeframe Active Treatment MNA	$ 420,000 $ 403,000 $ 443,000 $1,266,000 10 Years 100 years
	MNA	NA processes would be used to address contamination after COC concentrations in Zones 2 and 3 groundwater are protective of downgradient receptors. Groundwater monitoring would be conducted to assess progress toward RAOs.		
	LUCs	LUCs to prohibit aquifer use and intrusive activities to prevent exposure to contaminated groundwater and require evaluation of VI if future changes in building or land use occur.		

If Five-Year Review monitoring data indicate that natural attenuation will result in groundwater restoration timeframes longer than 100 years after active treatment is complete, optimization of the remedy, including additional injection events, will be required to increase the degradation rate of the remaining contaminants so that cleanup levels can be met in a reasonable timeframe.

2.10.2 Comparative Analysis of Alternatives

A comparative analysis using the **nine USEPA criteria** was completed and is provided below. The analyses are summarized in **Tables 13, 14,** and **15** for groundwater, respectively.

TABLE 13
Comparative Analysis of Alternatives, Zone 1

CERCLA Criteria	No Action	AS/SVE, MNA, LUCs, and VIMS	ISCO, MNA, LUCs, and VIMS	ERD, MNA, LUCs, and VIMS
	(1)	(2)	(3)	(4)
Threshold Criteria				
Protection of Human Health and the Environment	❍	●	●	●
Compliance with ARARs	❍	●	●	●
Primary Balancing Criteria				
Long-term Effectiveness and Permanence	Not Applicable	●	●	●
Reduction in Toxicity, Mobility, or Volume through Treatment	Not Applicable	⭘	●	●
Short-term Effectiveness	Not Applicable	⭘	⭘	●

TABLE 13
Comparative Analysis of Alternatives, Zone 1

CERCLA Criteria	No Action	AS/SVE, MNA, LUCs, and VIMS	ISCO, MNA, LUCs, and VIMS	ERD, MNA, LUCs, and VIMS
	(1)	(2)	(3)	(4)
Implementability	Not Applicable	❍	◉	◉
Present-worth Cost	$0	$2.91 M	$2.18 M	$2.63 M
Modifying Criteria				
State Acceptance	❍	●	●	●
Community Acceptance	NC	NC	NC	NC

Notes:

Relative Ranking: ● High ◉ Moderate ❍ Low

Rankings are provided as qualitative descriptions of the relative compliance of each alternative with the criteria. The No Action alternative is used as a baseline for comparison purposes only. Because it does not meet the threshold criteria, it is not a viable alternative and was not considered further.

M = million dollars

NC = No significant comments were received from Community Members

TABLE 14
Comparative Analysis of Alternatives, Zone 2

CERCLA Criteria	No Action	AS, MNA, LUCs, and VIMS	ISCO, MNA, LUCs, and VIMS
	(1)	(2)	(3)
Threshold Criteria			
Protection of Human Health and the Environment	❍	●	●
Compliance with ARARs	❍	●	●
Primary Balancing Criteria			
Long-term Effectiveness and Permanence	Not Applicable	●	●
Reduction in Toxicity, Mobility, or Volume through Treatment	Not Applicable	◉	●
Short-term Effectiveness	Not Applicable	◉	●
Implementability	Not Applicable	◉	◉
Present-worth Cost	$0	$10.69 M	$13.96 M
Modifying Criteria			
State Acceptance	❍	●	●
Community Acceptance	NC	NC	NC

Notes:

Relative Ranking: ● High ◉ Moderate ❍ Low

Rankings are provided as qualitative descriptions of the relative compliance of each alternative with the criteria. The No Action alternative is used as a baseline for comparison purposes only. Because it does not meet the threshold criteria, it is not a viable alternative and was not considered further.

M = million dollars

NC = No significant comments were received from Community Members

TABLE 15
Comparative Analysis of Alternatives, Zone 3

CERCLA Criteria	No Action (1)	MNA and LUCs (2)	Biobarrier, MNA, and LUCs (3)
Threshold Criteria			
Protection of Human Health and the Environment	❍	●	●
Compliance with ARARs	❍	●	●
Primary Balancing Criteria			
Long-term Effectiveness and Permanence	Not Applicable	✪	●
Reduction in Toxicity, Mobility, or Volume through Treatment	Not Applicable	❍	●
Short-term Effectiveness	Not Applicable	✪	●
Implementability	Not Applicable	●	✪
Present-worth Cost	$0	$0.54 M	$1.27 M
Modifying Criteria			
State Acceptance	❍	●	●
Community Acceptance	NC	NC	NC

Notes:
Relative Ranking: ● High ✪ Moderate ❍ Low
Rankings are provided as qualitative descriptions of the relative compliance of each alternative with the criteria. The No Action alternative is used as a baseline for comparison purposes only. Because it does not meet the threshold criteria, it is not a viable alternative and was not considered further.
M = million dollars
NC = No significant comments were received from Community Members

Threshold Criteria

Overall Protection of Human Health and the Environment

Overall protection of human health and the environment addresses whether each alternative provides adequate protection of human health and the environment and describes how risks posed through each exposure pathway are eliminated, reduced, or controlled, through treatment, engineering controls, and/or institutional controls.

All of the active alternatives are protective of human health and the environment by eliminating, reducing, or controlling risks posed by the site through remedial strategies, engineering controls, or LUCs.

The active alternatives for groundwater remediation in Zones 1, 2, and 3 are suitable for the treatment of groundwater containing COCs and for the reduction of risk to human receptors. Monitoring and LUCs would provide protection until RAOs are achieved.

Compliance with ARARs

Compliance with ARARs addresses whether a remedy will meet all of the applicable or relevant and appropriate requirements of other Federal and State environmental statutes or provides a basis for an invoking waiver. Section 121(d) of CERCLA and NCP §300.430(f)(1)(ii)(B) require that RAs at CERCLA sites at least attain legally applicable or relevant and appropriate Federal and State requirements, standards, criteria, and limitations which are collectively referred to as ARARs, unless such ARARs are waived under CERCLA section 121(d)(4).

All active alternatives are **expected to comply with ARARs**. The chemical-specific ARARs would be the same for all alternatives. Alternatives that involve injections or sparging (Zone 1 Alternatives 2, 3, and 4; Zone 2 Alternatives 2, and 3; and Zone 3 Alternative 3) would have to comply with underground injection control program requirements, whereas MNA (Zone 3 Alternative 2) would not.

Primary Balancing Criteria

Long-term Effectiveness and Permanence

Long-term effectiveness and permanence refers to expected residual risk and the ability of a remedy to maintain reliable protection of human health and the environment over time, once clean-up levels have been met. This criterion includes the consideration of residual risk that will remain onsite following remediation and the adequacy and reliability of controls.

Each alternative provides long-term protection that increases if mass transfer (volatilization) and treatment components are included. Reviews conducted at least every five years, as required by CERCLA, would be necessary to evaluate the effectiveness of any of the alternatives because hazardous substances would remain onsite at concentrations above levels that allow for unlimited use and unrestricted exposure. Due to the potential presence of DNAPL at the site, there is significant uncertainty to calculate the timeframe for reducing DNAPL and residual concentrations to the site cleanup levels. Restoration of an aquifer contaminated with DNAPL in a reasonable timeframe is not likely to be attained as DNAPL is often difficult to remove.

Zones 1 and 2: AS with SVE (Zone 1 Alternative 2) AS (Zone 2 Alternative 2), ISCO (Zone 1 Alternative 3, Zone 2 Alternative 3), and ERD (Zone 1 Alternative 4) are comparably rated for this criterion as they provide active treatment that removes the contaminant mass. Rebound is a potential issue with any air or liquid amendment injection strategy; therefore, subsurface distribution is the key to effectiveness and treatment timeframe. Because of the possibility of rebound, multiple injections (or system restart for AS) may be required. ERD (Zone 1 Alternative 4) may have a slightly higher long-term effectiveness because it may provide longer, more sustained reducing conditions within the aquifer after active treatment is complete, resulting in continued degradation of COCs. AS and ISCO may have slightly lower long-term effectiveness as they remove the contaminants using oxidation or air stripping which creates an aerobic environment, which is not conducive to continued degradation after treatment.

Zone 3: MNA (Zone 3 Alternative 2) is rated lower than the biobarrier and MNA (Zone 3 Alternative 3). The effectiveness and permanence of MNA as a standalone remedy in Zone 3 depends on NA processes, whereas the biobarrier uses active treatment to reduce the concentrations of COCs and then relies on NA to reduce COCs in groundwater to their respective cleanup levels. Therefore, the biobarrier with MNA will likely reach the cleanup levels in a shorter timeframe than MNA as a standalone remedy.

Reduction of Toxicity, Mobility, or Volume through Treatment

Reduction of toxicity, mobility, or volume through treatment refers to the anticipated performance of the treatment technologies that a remedy may employ in their ability to reduce toxicity, mobility, or volume of contamination.

Zone 1 and 2: AS and SVE (Zone 1 Alternative 2), AS (Zone 2 Alternative 2), ISCO (Zone 1 Alternative 3, Zone 2 Alternative 3), and ERD (Zone 1 Alternative 4) would reduce toxicity, mobility, and volume through treatment. The technologies are effective at reducing the concentrations of COCs in groundwater. Each would satisfy the statutory preference for treatment as a principal element.

ISCO (Zone 1 Alternative 3, Zone 2 Alternative 3) and ERD (Zone 1 Alternative 4) provide the highest reduction of toxicity, mobility, or volume through treatment followed by AS. ISCO is expected to provide the most rapid reduction in toxicity and volume of COCs in groundwater through chemical oxidation, while ERD would reduce contaminant concentrations at a slower rate because it depends on biological processes. AS would reduce toxicity and volume; however, AS is not a destructive process, and the transferred mass of VOCs, if not biodegraded aerobically or captured by SVE, would release into the atmosphere.

Zone 3: The biobarrier with MNA (Zone 3 Alternative 3) would reduce toxicity, mobility, or volume through treatment. Although MNA does not include active treatment, natural reduction of VOC concentrations through a variety of physical, chemical, or biological activities will occur over time.

Short-term Effectiveness

Short-term effectiveness addresses the period of time needed to implement the remedy and any adverse impacts that may be posed to workers, the community and the environment during construction and operation of the remedy until protectiveness is achieved, the time to achieve protectiveness of the remedy, and the time to achieve cleanup levels.

Short-term effectiveness, in terms of risks to workers, the community, and the environment are higher for the active treatments but would be minimized using appropriate personal protective equipment, air monitoring, and engineering controls to prevent spills or damage to the environment. Although the period of time to implement AS and ISCO would be similar to that for ERD, the risks to workers are generally higher for AS and ISCO than risks for ERD. This is attributable to the increased labor required to perform O&M on the AS system, the elevated risks associated with handling a strong oxidant during the ISCO injection and recirculation activities, and the potential for AS to increase risks to Base workers from VI into occupied buildings.

The potential environmental impacts (greenhouse gas or air pollutant emissions from running equipment or vehicles) and resource use (water or energy) were evaluated for each primary remedy (AS, ISCO, ERD, biobarrier, and MNA). In Zone 1, AS and ERD each had similarly high potential environmental impacts during implementation primarily from electricity use to power the systems (AS, SVE, and VIMS) or the environmental impact from manufacturing the substrate for injection and water used to dilute the substrate for injection. AS is estimated to require five years of active treatment. ISCO is estimated to require two years of active treatment. ERD is estimated to require four years of active treatment.

In Zone 2, AS would have higher potential environmental emissions from installation of the wells and operation of the AS, VIMS, and sewer ventilation system. AS is estimated to require five years of active treatment. ISCO in Zone 2 would have higher potential water usage primarily from dilution of the oxidant and some environmental impacts from manufacturing the oxidant. ISCO is estimated to require two years of active treatment. In Zone 3, the biobarrier would have higher environmental impacts than MNA alone because of the installation of the biobarrier wells, substrate production and injection, and increased sampling required for performance monitoring. The biobarrier is estimated to require 10 years of active treatment. MNA is estimated to require more than 100 years to achieve cleanup levels.

All alternatives are expected to be protective at the time of remedy implementation because LUCs would prevent exposure to COCs.

Implementability

Implementability addresses the technical and administrative feasibility of a remedy from design through construction and operation. Factors such as availability of services and materials, administrative feasibility, and coordination with other governmental entities are also considered.

Each alternative is technically and administratively feasible, with services and materials required to implement the remedy readily available. Subsurface injections of air or liquid amendments rely heavily on distribution throughout the affected aquifers. Because the aquifers are not uniform, preferential flow through more porous media may cause inadequate contact with contaminated groundwater, reducing the implementability of all alternatives involving injections.

Zones 1 and 2: ISCO (Zone 1 Alternative 3, Zone 2 Alternative 3) and ERD (Zone 1 Alternative 4) have moderate rankings for implementability because they involve drilling, construction, and maintenance activities. AS (Zone 1 Alternative 2, Zone 2 Alternative 2) is considered to have a low implementability because it involves the installation of extensive infrastructure to convey and recover air from the subsurface. Air injected into the subsurface would likely flow beneath clayey or fine-grained layers until it reaches a vertically upward pathway, potentially leading to uneven treatment or VI. SVE may also be difficult to implement because of the shallow depth of groundwater in Zone 1. Furthermore, for Zone 2, new VIMS may be needed for two buildings (Buildings 67 and 101) near the target treatment area. Existing VIMS in Buildings 3, 3B, 37, and 43, and the sewer mitigation system in Building HP57 would likely need to be upgraded, which would require significant design, labor, and startup monitoring.

Zone 3: MNA (Alternative 2) has a high ranking for implementability because it requires no construction, and the site labor is limited to sampling activities. The biobarrier and MNA (Alternative 3) has a moderate ranking for implementability because, like the active alternatives in Zones 1 and 2, it requires additional equipment and materials to implement.

Cost

Tables 10, 11, and **12** summarize the direct and indirect capital costs, as well as long-term O&M costs (as applicable) for the alternatives. For comparative purposes, a 30-year time frame with a 1.5 percent discount rate was used.

Zone 1: Costs for each alternative are between $2 and $3 million. ISCO (Alternative 3) is the least expensive alternative. ERD (Alternative 4) is the next least expensive alternative ($500,000 more than ISCO). AS (Alternative 2) is the most expensive option ($730,000 more than ISCO and $280,000 more than ERD).

Zone 2: Costs for each alternative range from $10 to $14 million. Costs for ISCO (Alternative 3) are higher than AS (Alternative 2), driven primarily by the oxidant. The first and second injection events include the same oxidant quantity; however, based on performance monitoring, the amount may be reduced for the second event. Additionally, there is uncertainty in the design, build, and startup of new VIMS and expansion of existing VIMS, which may require additional funds because of unanticipated challenges with installation and operation.

Zone 3: Costs for each alternative range from $0.5 to $1.5 million. Costs for the biobarrier (Alternative 3) are approximately $723,000 higher than costs for MNA (Alternative 2) because the biobarrier would require additional construction and active treatment. Costs for the biobarrier include five injection events and monitoring support for more than 10 years. If substrate persists longer, then fewer injections may be necessary.

Modifying Criteria

State Acceptance

State involvement has been solicited throughout the CERCLA process. NCDEQ, as the designated State support agency in North Carolina, concurs with the remedial alternatives evaluated and the Selected Remedy.

Community Acceptance

The public meeting was held on June 13, 2018 to present the PP and answer community questions regarding the proposed RA at Site 88. The questions and concerns raised at the meeting were general inquiries for informational purposes only. No comments requiring amendment to the PP were received from the public during the meeting and public comment period.

2.11 Selected Remedy

One alternative from each treatment zone was selected to comprise the Selected Remedy for remediation of groundwater and soil gas at Site 88. The Selected Remedy is shown on **Figures 11, 12,** and **13** and consists of:

- Zone 1: ERD via vertical injection wells to treat areas with PTW and groundwater with high COC concentrations at shallow depths near the source area (Alternative 4).
- Zone 2: ISCO via horizontal injection wells to treat areas with suspected PTW and groundwater with high COC concentrations at deeper depths downgradient from the source area (Alternative 3).
- Zone 3: Biobarrier via vertical injection wells treat the furthest downgradient groundwater contamination (Alternative 3).

FIGURE 12

Selected Remedy Cross Section

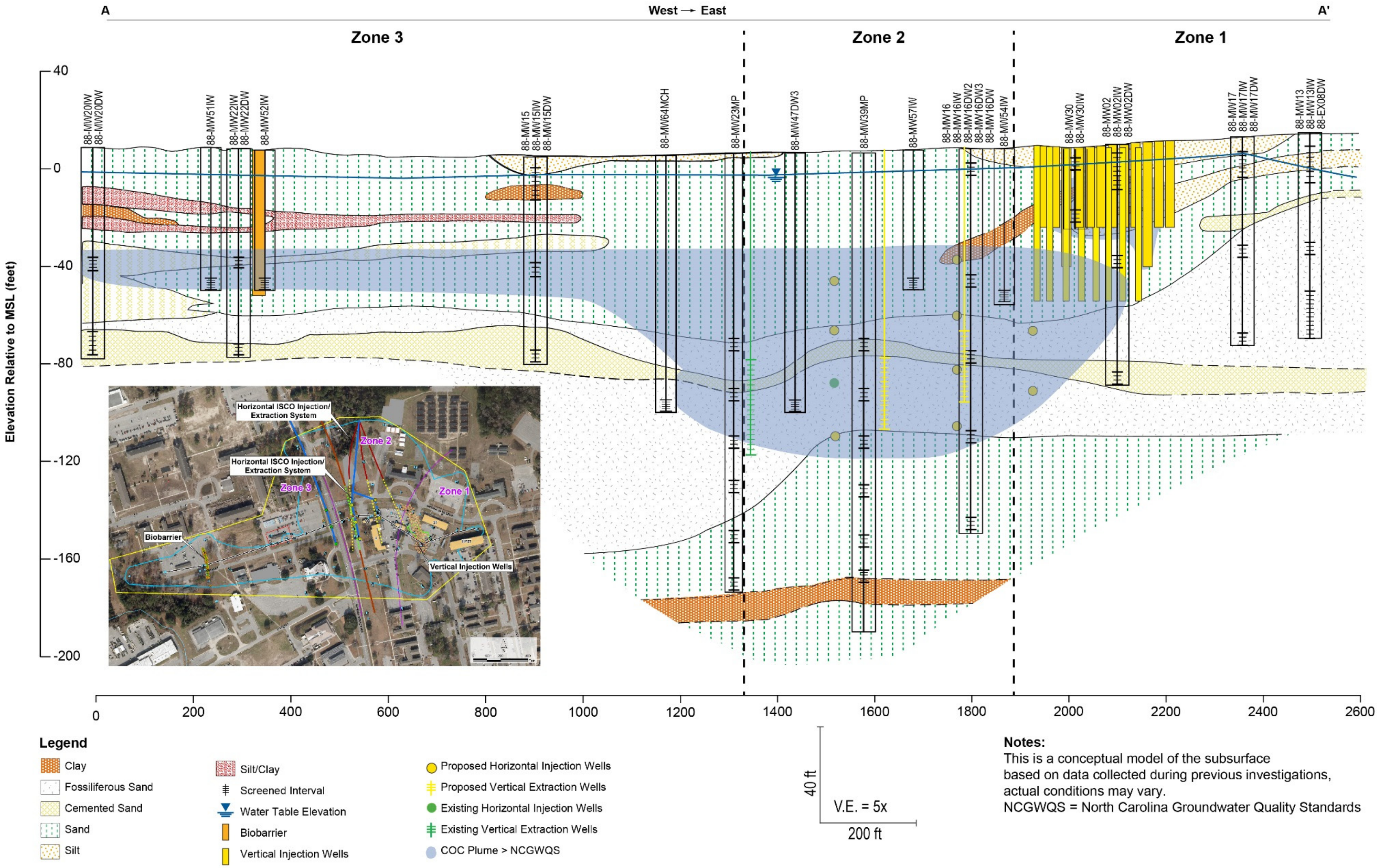
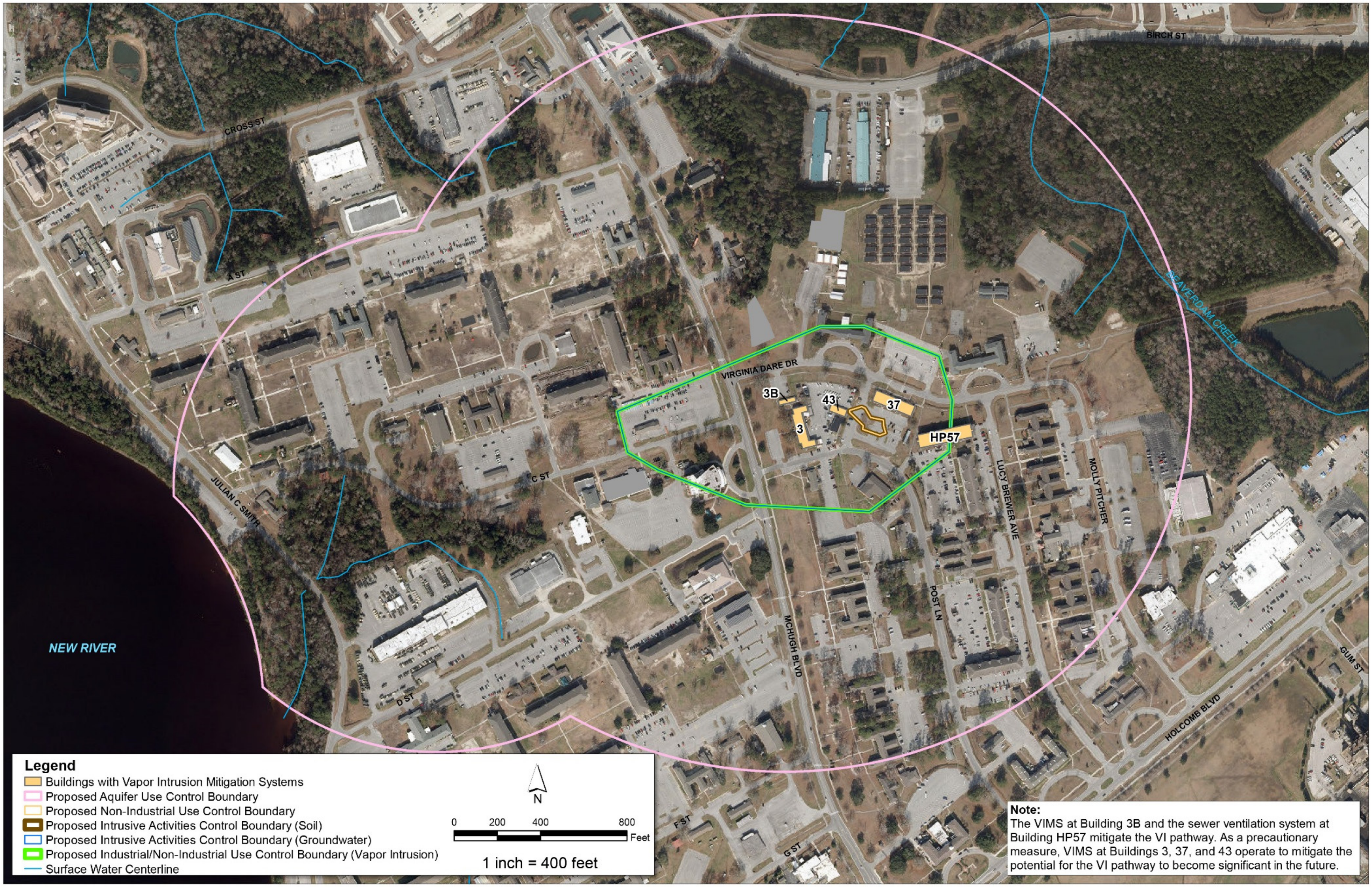


FIGURE 13
Proposed LUC Boundaries



- VI: Treatment of PTW and groundwater is expected to reduce groundwater concentrations below levels that result in VI pathways of concern. In the interim, continued operation and monitoring of the VIMS at Building 3B and the sewer ventilation system at Building HP57 will mitigate the VI pathway. As a precautionary measure, continued operation and monitoring of VIMS at Buildings 3, 37, and 43 will mitigate the potential for the VI pathway to become significant in the future.

LUCs will be implemented to prevent exposure to COCs in contaminated media. After active treatment is complete in each zone, MNA will be implemented to monitor the COCs in groundwater until cleanup levels are attained and RAOs are satisfied.

A more detailed description of each of these alternatives and the rationale for selection is included below.

2.11.1 Rationale for the Selected Remedy

Zone 1: Alternative 4 (ERD) via vertical injection wells with MNA, VIMS, and LUCs was selected for groundwater in Zone 1 because ERD has been proven effective at Site 88 during pilot studies, complies with ARARs, and is most effective in the short-term based on currently reducing conditions in the aquifer that are favorable for ERD. ERD is expected to reduce COCs to levels that will be protective of the New River within four years and then transition to MNA, and LUCs to provide protection until cleanup levels are achieved, and will reduce the volume of DNAPL present in the subsurface through treatment. Operation of the existing VIMS in Buildings 37 and 43 and the sewer ventilation system in Building HP57 will continue in order to prevent the VI pathway from being completed.

Zone 2: Alternative 3 (ISCO) via horizontal injection wells and recirculation with MNA, VIMS, and LUCs was selected for groundwater in Zone 2 because ISCO has been proven effective at Site 88 during pilot studies, complies with ARARs, is expected to reduce COCs to levels that are expected to be protective of the New River within four years and then transition to MNA, and LUCs to provide protection until cleanup levels are achieved, and will reduce the volume of DNAPL present in the subsurface through treatment. Despite the higher cost of Alternative 3 (ISCO), it was chosen because it will not require additional VI mitigation strategies that would be required under Alternative 2 (AS). Operation of the existing VIMS in Buildings 3 and 3B will continue in order to prevent the VI pathway from being completed.

Zone 3: Alternative 3 (Biobarrier) via vertical injection wells with MNA and LUCs was selected to address downgradient groundwater contamination in Zone 3. Despite the prediction that source area treatment coupled with NA will protect the New River, a containment strategy at approximately 1,300 feet downgradient of the source area will also help mitigate downgradient migration of COCs not treated by the source area treatment as a conservative measure. Furthermore, ERD has been proven effective at Site 88 in pilot studies, it protects human health and the environment, complies with ARARs, and it will reduce the toxicity, mobility, and volume of the COCs.

2.11.2 Description of the Selected Remedy

The Selected Remedy for groundwater and soil gas at Site 88 includes ERD using vertical injection wells in Zone 1, ISCO using horizontal injection wells and recirculation in Zone 2, a biobarrier via injection wells in Zone 3, sitewide MNA and LUCs, and continued operation and monitoring of VIMS at Buildings 3, 3B, 37, and 43 and the sewer ventilation system at Building HP57. The proposed locations of the vertical ERD, horizontal ISCO, and vertical biobarrier injection wells are shown on **Figures 11** and **12**.

Zone 1

Alternative 4 (ERD) involves the installation of 21 vertical injection wells screened in the surficial aquifer and 78 injection wells screened in the UCH aquifer, for a total of 99 injection wells as shown on **Figures 11** and **12**. Substrate injections are expected to be required every two years for four years. During active treatment, groundwater performance monitoring will be conducted to measure the effectiveness of ERD and changes in COC concentrations. The specific details regarding active treatment objectives and performance monitoring will be presented in the Remedial Design (RD).

Zone 2

Alternative 3 (ISCO) involves the installation of nine horizontal injection wells and five vertical extraction wells, for a total of 10 injection wells and 8 extraction wells as shown on **Figures 11** and **12**. It is estimated that two permanganate injection events will be needed and operation of the recirculation system will continue for approximately one year post-injection. During active treatment, groundwater performance monitoring will be conducted to measure the effectiveness of ISCO and changes in COC concentrations. The specific details regarding active treatment objectives and performance monitoring will be presented in the RD.

Zone 3

Alternative 3 (Biobarrier) will involve the installation of ten new vertical injection wells near the four existing injection wells, creating a biobarrier that is approximately 280 feet long, as shown in **Figures 11** and **12**. Substrate injections are expected to be required every two years until groundwater COCs concentrations are protective of downgradient receptors, based on fate and transport modeling, or until it is determined that biodegradation can be maintained naturally and further enhancements are not required. During active treatment, groundwater performance monitoring will be conducted to measure the effectiveness of ERD and changes in COC concentrations. The specific details regarding active treatment objectives and performance monitoring will be presented in the RD.

Zone 1 and 2 VIMS

The VIMS are active subslab depressurization systems that use fans to place a negative pressure beneath the floor slab under the footprint of the building. The negative pressure reverses the flow of contaminants into the indoor space and removes subslab VOCs. Within Zone 1, VIMS were installed and are currently operational in Buildings 37 and 43, and a sewer ventilation system has been installed and is operational at Building HP57. Within Zone 2, VIMS were installed in Buildings 3 and 3B. The continued operation of each system will be reevaluated based on site conditions by the USMC, Navy, USEPA, and NCDEQ. The following lines of evidence may be considered to evaluate VIMS shutdown:

- Results of rebound testing
- Additional indoor air and soil gas sampling
- Building-specific attenuation factors
- Other empirical evidence

Specific details including sampling frequency, measurement instruments, analytical methods, and operating procedures will be included in the RD.

Sitewide

Once active treatment is complete in Zones 1 and 2, MNA will take effect to monitor the plume until contaminant concentrations are such that would allow for unlimited use and unrestricted exposure. Monitoring details such as specific sampling locations, frequency, and NA data to collect will be presented in the RD. The following lines of evidence will be considered and discussed with the regulatory agencies and stakeholders when evaluating the transition from active treatment to MNA or an alternate treatment technology:

- Plume stability
  - COC concentrations above the cleanup levels not observed in perimeter and/or sentinel wells
  - COC concentrations in downgradient plume wells not statistically increasing, as determined by Mann-Kendall or similar trend analysis, for three successive sampling events
  - Decreasing or stable-to-decreasing concentrations of COCs in samples collected from near-source wells
- Groundwater fate and transport modeling indicating protectiveness of the New River
- Magnitude of total molar mass reduction over time

- Elimination of NAPL to the extent practicable, based on groundwater concentrations in excess of one percent of the solubility of PCE (2 mg/L)
- Sustained favorable MNA conditions, including one or more of the following:
  - Increasing degradation daughter products
  - Presence of favorable microbial populations
  - Favorable geochemical parameters (low or no dissolved oxygen, neutral pH, negative oxidation-reduction potential)

LUCs including, but not limited to, land use restrictions in the Base Master Plan, deed and/or lease restrictions, and administrative procedures to prohibit unauthorized aquifer use and intrusive activities (for example, excavation, well installation, or construction), require evaluation of VI if future changes in building or land use occur, and prohibit residential use will be implemented as part of the remedy to prevent exposure to the residual contamination on the site that exceeds the cleanup levels. The LUCs will be implemented and maintained by the Navy and MCB Camp Lejeune until the concentration of hazardous substances in the soil and groundwater are at such levels to allow for unlimited use and unrestricted exposure. The LUC performance objectives include:

- Prohibit potable use of groundwater from the surficial and Castle Hayne aquifers underlying Site 88.
- Prohibit residential uses and development at the site within the former ZVI soil mixing area.
- Prohibit unauthorized intrusive activities in areas with contaminated groundwater, soil gas, and within the ZVI soil mixing area.
- Maintain the integrity of any existing or future monitoring or remediation system at the site such as monitoring wells, treatment systems, and VIMS.
- Evaluate the potential for future VI pathways.

To achieve the LUC objectives, the Navy will implement the following LUCs for Site 88:

- **Aquifer Use Control Boundary:** Prohibit the withdrawal and use of groundwater, except for environmental monitoring, where groundwater contamination remains in place above concentrations that allow for unlimited use and unrestricted exposure. This LUC boundary encompasses the area within 1,000 feet of groundwater within the surficial and Castle Hayne aquifers with concentrations of COCs exceeding the more conservative values between the NCGWQS or the federal MCLs.
- **Intrusive Activities Control Boundary (Groundwater and Soil Gas):** Restrict intrusive activities within 100 feet of the extent of groundwater contamination with concentrations above the cleanup levels.
- **Industrial/Non-Industrial Use Control (Vapor Intrusion):** Before construction of new buildings or structural modifications to existing buildings, the potential for VI will be evaluated by assessing multiple lines of evidence. If the results of the evaluation indicate that VI could result in unacceptable indoor air concentrations, then engineering controls or an action to address the source will be considered to mitigate the unacceptable exposure. This LUC boundary encompasses the area within 100 feet of groundwater with concentrations of VOCs exceeding the cleanup levels.
- **Intrusive Activities Control Boundary (Soil):** Prohibit intrusive activities within the former ZVI soil mixing treatment area.
- **Non-industrial Use Control Boundary (Soil):** Prohibit non-industrial land use within the ZVI soil mixing treatment area.

The Navy will implement the following actions as part of the LUCs for Site 88:

- Incorporating land and groundwater use prohibitions into the MCB Camp Lejeune Base Master Plan.

- Recording a Notice of Contaminated Site filed in Onslow County real property records in accordance with North Carolina General Statutes 143B-279.9 and 143B-279.10.
- Maintaining the integrity of any current or future remedial or monitoring system, such as conducting site inspections to verify compliance with use restrictions.

The estimated LUC boundaries are provided in **Figure 13** while the actual LUC boundaries will be finalized in the RD. The LUC implementation actions, including monitoring and enforcement requirements, will be provided in a LUC Implementation Plan (LUCIP) that will be prepared by the Navy after the ROD has been finalized. The Navy will submit the LUCIP to USEPA and NCDEQ for review and approval pursuant to the primary document review procedures stipulated in the FFA. The Navy will maintain, monitor (including conducting periodic inspections), and enforce the LUCs according to the requirements contained in the LUCIP and the ROD. The need for LUCs to prevent exposure and ensure protection will be periodically reassessed as COC concentrations are reduced over time.

Because COCs will remain at the site above levels that allow for unlimited use and unrestricted exposure, the Navy will review the RA at least every five years after initiation of the RA, in accordance with CERCLA Section 121(c) and the NCP at 40 CFR 300.4309(f)(4)(ii). If results of the five-year reviews reveal that the remedy is not protective of human health, additional RAs would be evaluated by the parties and implemented by the Navy.

2.11.3 Expected Outcomes of the Selected Remedy

A summary of the expected outcomes of the Selected Remedy is provided on **Table 16**. Current land uses are expected to continue at Site 88 and there are no other planned land uses in the foreseeable future, or for development of adjacent lands. Cleanup levels for the Selected Remedy are based on unlimited use and unrestricted exposure. Exposure will be controlled through LUCs until COCs in groundwater are reduced to the cleanup levels. When remediating sites where groundwater concentrations indicate the presence of DNAPL, complete remediation to site-specific cleanup levels will likely require integrated strategies such as a combination of multiple treatments or application of more than one technology, adoption of alternate end points for defining success, and long-term management after active remediation. Therefore, to expediently remediate the site, aggressive treatment with a dense network of treatment points and multiple rounds of treatment are components of the Selected Remedy. If cleanup levels are not being met within a reasonable timeframe, additional active treatment, such as reinjections, can be conducted. If the selected groundwater remedy is not effective, then the remedy may be modified to include additional actions for contaminated soil, if data suggest that contaminated soil is acting as a continuing source of groundwater contamination. Modifications to the Selected Remedy may be required over time and may include, but are not limited to, changes in the design or operation of one or more of the selected remedies. The Navy and USMC, in partnership with the USEPA and with concurrence from NCDEQ, may also change technologies as long as the relevant RA plan concludes that the new technology would meet the RAOs and the following performance criteria:

- Protection of human health and the environment
- Compliance with ARARs

The Zone 3 biobarrier wall will be maintained until groundwater COCs concentrations are protective of downgradient receptors, based on fate and transport modeling, or until it is determined that biodegradation can be maintained naturally and further enhancements are not required.

MNA will be conducted after active treatment components are implemented and until each COC is at or below its respective cleanup levels for four consecutive monitoring events. The Navy and USMC, in partnership with the USEPA and NCDEQ, will evaluate the discontinuation of monitoring of individual COCs that have met the cleanup levels after four rounds based on site conditions.

Once RAOs have been achieved, Site 88 is expected to be suitable for unlimited use and unrestricted exposure. Therefore, the Navy, USEPA, and NCDEQ may agree for the LUC component of the Selected Remedy to be terminated at site closeout.

TABLE 16

Expected Outcomes

Basis for Action	RAO	Remedy Component	Metric	Expected Outcome
Future residential exposure to COCs in groundwater and soil gas. Construction worker exposure to COCs in groundwater and soil gas.	Reduce groundwater contaminant source mass to the maximum extent practicable within a reasonable timeframe to inhibit migration of COCs to the New River	ERD	For Zones 1 and 2, continue treatment applications as described in the RD or multiple lines of evidence of MNA are observed including: • Plume stability • Mass reduction • Elimination of NAPL to the extent practicable, based on groundwater concentrations in excess of one percent of the solubility of PCE • Groundwater fate and transport modeling indicating protectiveness of the New River • Sustained favorable MNA conditions	MNA
		ISCO		
		Biobarrier	Maintain until COC concentrations in groundwater are protective of downgradient receptors (based on fate and transport modeling) and aquifer conditions suggest that biodegradation can be maintained naturally, and further enhancements are not required.	
	Restore groundwater quality to meet NCDEQ and federal primary drinking water standards based on the classification of the aquifer as a potential source of drinking water (Class GA or Class GSA) under 15A North Carolina Administrative Code (NCAC) 02L.0201.	MNA	Implement until each groundwater COC is at or below the more conservative values between the NCGWQS or the federal MCLs for four consecutive monitoring events.	Unlimited use and unrestricted exposure
	Prevent human ingestion of and contact with groundwater containing COCs at concentrations above NCGWQS or MCLs, whichever is more stringent.	LUCs	Implement LUCs until each groundwater COC is at or below the more conservative values between the NCGWQS or the federal MCLs for four consecutive monitoring events.	

TABLE 16
Expected Outcomes

Risk	RAO	Remedy Component	Metric	Expected Outcome
	Prevent exposure to COCs in groundwater and soil gas during construction, and through the VI pathway that could result in an unacceptable risk to human health.	LUCs/VIMS	Implement LUCs until each groundwater COC is at or below its respective cleanup level for four consecutive monitoring events. Once groundwater concentrations are below the cleanup levels (that incorporate the VISLs, **Table 9**), soil gas concentrations are expected to be below concentrations likely to result in a complete VI pathway or unacceptable risk to construction workers. Soil gas confirmation samples will be collected and compared to soil gas cleanup levels. While LUCs are in place, if groundwater concentrations are detected above cleanup levels within 100 feet of a building without a VIMS or sewer ventilation system, a VI evaluation will be conducted. This evaluation will determine whether the potential for a complete VI pathway has changed from previous assessments and whether additional sampling is required. Operate the Building 3B VIMS and Building HP57 sewer ventilation system until active treatment in Zones 1 and 2 are complete and shutdown criteria, as established in the RD, are met. The following lines of evidence may be considered to evaluate VIMS and sewer ventilation system shutdown: • Results of rebound testing • Additional indoor air and soil gas sampling • Building-specific attenuation factors • Other empirical evidence	
Although there are no soil COCs, VOCs remain in soil within the ZVI soil mixing area at concentrations exceeding soil-to-groundwater MSCCs, suggesting that contaminated soil could serve as a continuing source to groundwater.	Restrict intrusive activities and prevent residential use within the ZVI soil mixing treatment area.	LUCs	Maintain and monitor LUCs quarterly. If the groundwater remedy cannot achieve the RAOs and data suggest that contaminated soil is acting as a continuing source of groundwater contamination, then additional soil remediation actions will be evaluated.	Parking Lot

2.11.4 Statutory Determinations

RAs undertaken at NPL sites must meet the statutory requirements of Section 121 of CERCLA and thereby achieve adequate protection of human health and the environment, comply with ARARs of both federal and state laws and regulations, be cost-effective, and use, to the maximum extent practicable, permanent solutions and alternative treatment or resource recovery technologies. In addition, CERCLA includes a preference for remedies that employ treatment that permanently and significantly reduces the volume, toxicity, and/or mobility of hazardous waste as the principal element. The following discussion summarizes the statutory requirements that are met by the Selected Remedy.

Protection of Human Health and the Environment—The Selected Remedy will protect human health and the environment by reducing site risks through groundwater treatment and the implementation of LUCs, mitigating VI pathways, and maintaining the integrity of any existing or future monitoring or remediation system at the site. Because current land use poses no unacceptable risks, implementation of the Selected Remedy will not pose unacceptable short-term risks or cross-media impacts. In Zones 1 and 2, active treatment will reduce DNAPL and elevated COC concentrations. After implementation of active treatment remedy components, MNA will take effect to monitor the plume until contaminant concentrations attain cleanup levels and RAOs are achieved. In Zone 3, the biobarrier will actively reduce COC concentrations providing increased protection of human health and the environment by inhibiting migration of COCs to the New River. Once biodegradation can be maintained naturally and further enhancements are not required, MNA will take effect to monitor the plume until contaminant concentrations attain cleanup levels and RAOs are achieved.

Compliance with ARARs—Section 121(d) of CERCLA, as amended, specifies, in part, that RAs for cleanup of hazardous substances must comply with requirements and standards under federal or more stringent state environmental laws and regulations that are applicable or relevant and appropriate (i.e., ARARs) to the hazardous substances or particular circumstances at a site or obtain a waiver. See also 40 CFR § 300.430(f)(1)(ii)(B). ARARs include only federal and state environmental or facility citing laws and regulations and do not include occupational safety or worker protection requirements. Compliance with Occupational Safety and Health Administration (OSHA) standards is required by 40 CFR §300.150; therefore, the CERCLA requirement for compliance with or wavier of ARARs does not apply to OSHA standards. In addition to ARARs, the lead and support agencies may, as appropriate, identify other advisories, criteria, or guidance to-be-considered for a particular release. In accordance with 40 CFR § 300.400(g), the Navy, USEPA and NCDEQ have identified the ARARs for the Selected Remedy. **Appendix A** lists the Chemical- and Action-Specific ARARs for the Selected Remedy. The Selected Remedy will meet all identified ARARs.

Cost-Effectiveness—The Selected Remedy is cost-effective and represents a reasonable value for the money to be spent. The following definition was used to determine cost-effectiveness, "A remedy shall be cost-effective if its costs are proportional to its overall effectiveness" (NCP §300.430(f)(1)(ii)(D). This analysis was accomplished by evaluating the overall effectiveness of those alternatives that satisfied the threshold criteria. In Zone 1, the estimated present worth cost of the Selected Remedy (ERD) is $2.63M, which is $450,000 more than the least expensive (ISCO); however, ERD has more favorable short-term effectiveness and, therefore, the remedy is cost-effective. In Zone 2, the estimated present worth cost of the Selected Remedy (ISCO) is $13.96M, which is $3.27M more than the least expensive (AS); however, ISCO will provide a significant increase in protection of human health and the environment by treating the source materials constituting PTW while not creating an increased potential for vapor intrusion pathways and is therefore cost-effective. In Zone 3, the Selected Remedy (biobarrier) is $1.27M, which is $730,000 more than the least expensive (MNA). Like Zone 2, the Selected Remedy will provide increased protection of human health and the environment by protecting downgradient receptors and is cost-effective.

Utilization of Permanent Solutions and Alternative Treatment Technologies or Resource Recovery Technologies to the Maximum Extent Practicable—The Selected Remedy represents the maximum extent to which permanent solutions and treatment technologies can be used in a practicable manner at Site 88. Because long-term effectiveness and permanence along with reduced toxicity and volume are achieved in the shortest timeframe with the Selected Remedy, the Navy, MCB Camp Lejeune, USEPA, and NCDEQ determined that the Selected Remedy provides the best balance of tradeoffs in terms of the balancing criteria while also considering the statutory preference for treatment as a principal element and considering State and community acceptance.

The Selected Remedy treats the source materials constituting PTW to the extent practicable, achieving significant COC reductions, protecting downgradient receptors, and mitigating future VI pathways. The Selected Remedy does not present short-term risks, such as potential for VI, different from the other treatment alternatives. There are no special implementability issues that sets the Selected Remedy apart from any of the other alternatives evaluated.

Preference for Treatment as a Principal Element—The Selected Remedy uses treatment as a principal element, and therefore satisfies the statutory preference for treatment. By oxidizing or degrading COCs, ISCO and ERD provide contaminant destruction.

Five-Year Review Requirements— Because the Selected Remedy will result in hazardous substances, pollutants, or contaminants remaining onsite in groundwater and soil gas above levels that allow for unlimited use and unrestricted exposure, a statutory review will be conducted within five years after the initiation of the RA to ensure that the remedy is, or will be, protective of human health and the environment in accordance with CERCLA Section 121(c) and the NCP at 40 CFR 300.430 (f)(4)(ii). If results of the five-year reviews reveal that the Selected Remedy is not protective of human health, additional RAs would be evaluated by the parties and implemented by the Navy.

2.12 Community Participation

The Navy, MCB Camp Lejeune, USEPA, and NCDEQ provide information regarding the cleanup of MCB Camp Lejeune to the public through the community relations program which includes a Restoration Advisory Board, public meetings, the AR file for the site, and announcements published in local newspapers. Restoration Advisory Board meetings continue to be held to provide an information exchange among community members, the Navy, MCB Camp Lejeune, USEPA, and NCDEQ. These meetings are open to the public and are held quarterly.

In accordance with Sections 113 and 117 of CERCLA, the Navy provided a public comment period from June 1, 2018 through July 2, 2018 for the PP for Site 88. A public meeting to present the PP was held on June 13, 2018 at the Carolina Coastal Community College. Public notice of the meeting and availability of documents was placed in *The Jacksonville Daily News*, *The Globe*, and the *RotoVu* newspapers on May 8 and May 19, May 10 and May 17, and May 9, respectively.

The PP for Site 88 was released for public comment on June 1, 2018. The PP identified Alternative 4, ERD with LUCs, MNA, and VIMS, as the preferred alternative for groundwater remediation in Zones 1; Alternative 3, ISCO with LUCs, MNA, and VIMS in Zone 2; and Alternative 3, Biobarrier with LUCs, MNA for groundwater remediation in Zone 3.

The AR, Community Involvement Plan, IRP fact sheets, and final technical reports concerning Site 88 can be obtained from the IRP web site: http://go.usa.gov/Dy5T. Internet access is available to the public at the following location:

Onslow County Public Library
58 Doris Avenue East
Jacksonville, North Carolina 28540
(910) 455-7350

2.13 Documentation of Significant Changes

The PP for Site 88 was released for public comment on June 1, 2018. No comments were submitted during the public comment period.

Benzene and 1,4-dichlorobenzene were identified in the PP as soil gas COCs. These constituents were not retained as COCs because the maximum concentrations are less than the adjusted USEPA VISLs for a Target Cancer Risk of 1.0×10^{-4} and HQ of 1.0.

3 Responsiveness Summary

The participants in the Public Meeting held on June 13, 2018, included representatives of the Navy, MCB Camp Lejeune, USEPA, and NCDEQ. Questions received during the public meeting were general inquiries and are described in the public meeting minutes in the AR. There were no comments received at the public meeting requiring amendment to the PP and no additional written comments, concerns, or questions were received from community members during the public comment period.

References

Reference Number	Reference Phrase in ROD	Location in ROD	Identification of Referenced Document Available in the Administrative Record
1	Chemicals of concern	Section 1.4	Feasibility Study Site 88, Operable Unit Number 15, Marine Corps Base, Camp Lejeune, North Carolina. Sections 3.3 and 3.4, Tables 3-4 and 3-5. CH2M HILL. October 2017
2	Vapor intrusion mitigation systems (VIMS)	Section 1.4	Phase II Vapor Intrusion Evaluation Report, Volume 2 of 5 – Mainside, Marine Corps Base, Camp Lejeune, North Carolina. Section 4.4.1. CH2M HILL. October 2011
3	Three treatment zones	Section 1.4	Feasibility Study Site 88, Operable Unit Number 15, Marine Corps Base, Camp Lejeune, North Carolina. Section 4.1. CH2M HILL. October 2017
4	Enhanced Reductive Dechlorination (ERD)	Section 1.4	Feasibility Study Site 88, Operable Unit Number 15, Marine Corps Base, Camp Lejeune, North Carolina. Section 4.5.4. CH2M HILL. October 2017
5	In-situ chemical oxidation (ISCO)	Section 1.4	Feasibility Study Site 88, Operable Unit Number 15, Marine Corps Base, Camp Lejeune, North Carolina. Section 4.6.3. CH2M HILL. October 2017
6	Biobarrier	Section 1.4	Feasibility Study Site 88, Operable Unit Number 15, Marine Corps Base, Camp Lejeune, North Carolina. Section 4.7.3. CH2M HILL. October 2017
7	Land use controls (LUCs)	Section 1.4	Feasibility Study Site 88, Operable Unit Number 15, Marine Corps Base, Camp Lejeune, North Carolina. Section 4.2. CH2M HILL. October 2017
8	Monitored natural attenuation (MNA)	Section 1.4	Feasibility Study Site 88, Operable Unit Number 15, Marine Corps Base, Camp Lejeune, North Carolina. Section 4.2. CH2M HILL. October 2017
9	Underground storage tanks (USTs)	Section 2.1	Remedial Investigation, Operable Unit Number 15, Marine Corps Base, Camp Lejeune, North Carolina. Executive Summary. CH2M HILL. March 2008
10	Varsol	Section 2.1	Remedial Investigation, Operable Unit Number 15, Marine Corps Base, Camp Lejeune, North Carolina. Section 2.3. CH2M HILL. March 2008
11	PCE	Section 2.1	Remedial Investigation, Operable Unit Number 15, Marine Corps Base, Camp Lejeune, North Carolina. Section 2.3. CH2M HILL. March 2008
12	Hydrogeologic units	Section 2.2	Hydrogeologic Framework of U.S. Marine Corps Base at Camp Lejeune, North Carolina. Pgs. 24 -34. Cardinell et al. 1993
13	Conceptual site model (CSM)	Section 2.3	Feasibility Study Site 88, Operable Unit Number 15, Marine Corps Base, Camp Lejeune, North Carolina. Section 2.7.1. CH2M HILL. October 2017
14	DNAPL source investigation	Table 1	DNAPL Site Characterization using a Partitioning Interwell Tracer Test at Site 88, Marine Corps Base, Camp Lejeune, North Carolina. Section 1.2. Duke Engineering and Services. July 1999

Reference Number	Reference Phrase in ROD	Location in ROD	Identification of Referenced Document Available in the Administrative Record
15	Surfactant was continuously injected	Table 1	Surfactant Enhanced Aquifer Remediation Demonstration (Site 88), Operable Unit 15, Marine Corps Base, Camp Lejeune, North Carolina. Duke Engineering and Services. January 2000
16	Butyric acid and yeast extract	Table 1	Reductive Anaerobic Biological In-Situ Treatment Technology Treatability Testing, Marine Corps Base, Camp Lejeune, North Carolina. Section 4.4. Battelle Memorial Institute. February 2003
17	Sewer survey	Table 1	Site 88 Building 25 Source Removal Engineering Evaluation / Cost Estimate Operable Unit Number 15, Marine Corps Base, Camp Lejeune, North Carolina. Section 2.12. CH2M HILL. September 2004
18	Shallow soil mixing	Table 1	Site 88 Building 25 Source Removal Non-Time Critical Removal Action Report Operable Unit Number 15, Marine Corps Base, Camp Lejeune, North Carolina. Section 4.1. AGVIQ/CH2M HILL Joint Venture. August 2006
19	Phased Basewide VI evaluation	Table 1	Vapor Intrusion Evaluation Report, Marine Corps Base Camp Lejeune, Jacksonville, North Carolina. March. Marine Corps Base Camp Lejeune, Jacksonville, North Carolina. November. AGVIQ/CH2M. November 2009 Phase III Vapor Intrusion Evaluation Report, Volume 2 of 5 - Mainside, Marine Corps Base, Camp Lejeune, North Carolina. Prepared for Naval Facilities Engineering Command, Atlantic Division, Norfolk, VA. CH2M. 2011
20	VIMS operation and maintenance was initiated in 2012	Table 1	Vapor Intrusion Mitigation System Year 1 Annual Monitoring Report. Marine Corps Installations East-Marine Corps Base Camp Lejeune, North Carolina. April. CH2M. 2014
21	Geophysical survey	Table 1	Geophysical Investigation Results Operable Unit Number 15 (Site 88), Marine Corps Base, Camp Lejeune, North Carolina. CH2M HILL. October 2009
22	Viscosity modification	Table 1	Polymer-Enhanced Subsurface Delivery and Distribution of Permanganate, Marine Corps Base, Camp Lejeune, North Carolina. Section 5.7. ESTCP. February 2013
23	Pilot-scale tests	Table 1	Feasibility Study Site 88, Operable Unit Number 15, Marine Corps Base, Camp Lejeune, North Carolina. Sections 4.6 and 4.7. CH2M HILL. October 2017
24	Limited site assessment	Table 1	Limited Site Assessment Report Former UST-25 Building 25 at Post Lane. CH2M HILL. July 2011
25	Solid waste management unit 615	Table 1	Solid Waste Management Unit 615, Marine Corps Base, Camp Lejeune, North Carolina. Background. CH2M HILL. February 2016.
26	NCDEQ accepted the recommendation	Table 1	Transfer of Solid Waste Management Unit 615, Marine Corps Base, Camp Lejeune, North Carolina. North Carolina Waste Management. January 2016
27	An uncapped sewer pipe	Table 1	Building HP57 Additional Vapor Intrusion Investigation (Site 88), Marine Corps Base, Camp Lejeune, North Carolina. Section 2.3 CH2M HILL. May 2015.
28	Ventilation of the sewer line	Table 1	Feasibility Study Site 88, Operable Unit Number 15, Marine Corps Base, Camp Lejeune, North Carolina. Section 2.5.4. CH2M HILL, October 2017
29	Tracer study	Table 1	Feasibility Study Site 88, Operable Unit Number 15, Marine Corps Base, Camp Lejeune, North Carolina. Section 2.5.3. CH2M HILL, October 2017
30	Predictive Modeling	Section 2.5.2	Feasibility Study Site 88, Operable Unit Number 15, Marine Corps Base, Camp Lejeune, North Carolina. Section 4.3. CH2M HILL, October 2017

Reference Number	Reference Phrase in ROD	Location in ROD	Identification of Referenced Document Available in the Administrative Record
31	Human health and ecological risks	Section 2.7	Remedial Investigation Site 88, Operable Unit 15, Marine Corps Base, Camp Lejeune, North Carolina. Sections 7 and 8. CH2M HILL. March 2008
32	Collected within the soil mixing treatment area	Section 2.7.1	Feasibility Study Site 88, Operable Unit Number 15, Marine Corps Base, Camp Lejeune, North Carolina. Section 2.7.1. CH2M HILL, October 2017
33	Remedial Action Objectives (RAOs)	Section 2.7	Feasibility Study Site 88, Operable Unit Number 15, Marine Corps Base, Camp Lejeune, North Carolina. Section 3.2. CH2M HILL, October 2017
34	Screening of technologies	Section 2.10.1	Feasibility Study Site 88, Operable Unit Number 15, Marine Corps Base, Camp Lejeune, North Carolina. Section 3.4. CH2M HILL, October 2017
35	Applicable or Relevant, and Appropriate Requirements (ARARs)	Section 2.10.1	Feasibility Study Site 88, Operable Unit Number 15, Marine Corps Base, Camp Lejeune, North Carolina. Tables 3-1, 3-2, and 3-3. CH2M HILL, October 2017
36	Nine USEPA criteria	Section 2.10.2	Feasibility Study Site 88, Operable Unit Number 15, Marine Corps Base, Camp Lejeune, North Carolina. Section 5.3 and Table 5-2. CH2M HILL, October 2017
37	Expected to comply with ARARs	Section 2.10.2	Feasibility Study Site 88, Operable Unit 15, Marine Corps Base, Camp Lejeune, North Carolina. Section 5.3.2 and Appendix J. CH2M HILL. October 2017.

Appendix A
ARARs

TABLE A-1
Chemical-Specific ARARs
Site 88 Record of Decision
MCB Camp Lejeune, North Carolina

Federal and North Carolina Chemical-Specific ARARs			
Media	**Requirement**	**Prerequisite**	**Citation**
Classification of contaminated groundwater	Groundwaters in the state naturally containing 250 mg/L or less of chloride are *classified as GA (Existing or potential source of drinking water supply for humans)* under 15A NCAC 02L .0201(1)	Groundwaters located within the boundaries or under the extraterritorial jurisdiction of the State of North Carolina **- Applicable**	15A NCAC 02L .0302(1)
	Groundwaters in the state naturally containing greater than 250 mg/L of chloride are *classified as GSA* under 15A NCAC 02L .0201(2)		15A NCAC 02L .0302(2)
Restoration of contaminated groundwater	Provides groundwater quality standards for contaminants as a maximum concentration. The following remedial goals have been set using this criteria. · Benzene (1 µg/L) · Naphthalene (6 µg/L) · cis-1,2-DCE (70 µg/L) · PCE (0.7 µg/L) · TCE (3 µg/L) · Vinyl Chloride (0.03 µg/L)	Class GA or GSA groundwaters with contaminant(s) concentrations exceeding standards listed in 15A NCAC 02L .0202 **- Relevant and appropriate**	15A NCAC 02L .0202(a), (b), and (g)
	Shall not exceed the Safe Drinking Water Action National Revied Primary Drinking Water Regulations: MCLs for organic contaminants specified in 40 CFR 141.61(a). · Benzene (5 µg/L) · cis-1,2-DCE (70 µg/L) · PCE (5 µg/L) · TCE (5 µg/L) · Vinyl Chloride (2 µg/L)	Groundwater classified as GA or GSA which are an existing or potential source of drinking water - **Relevant and appropriate**	40 CFR 141.61(a)

Notes:
µg/L = microgram per liter
PCE = tetrachloroethene
TCE = trichloroethene
DCE = dichloroethene

Federal and North Carolina Action-Specific ARARs			
Action	**Requirements**	**Prerequisite**	**Citation(s)**
General construction standards – All land–disturbing activities (i.e., excavation, trenching, grading etc.)			
Managing storm water runoff from land-disturbing activities	Shall install erosion and sedimentation control devices and practices sufficient to retain the sediment generated by the land-disturbing activity within the boundaries of the tract during construction.	Land-disturbing activity (as defined in N.C.G.S. Ch. 113A-52) of more than 1 acre of land – **relevant and appropriate**	N.C.G.S. Ch.113A-157(3) *Mandatory standards for land-disturbing activity*
	Shall plant or otherwise provide permanent ground cover sufficient to restrain erosion after completion of construction.		N.C.G.S. Ch.113A-157(3)
	The land-disturbing activity shall be conducted in accordance with the approved erosion and sedimentation control plan. *NOTE: Plan which meets the objectives of 15A NCAC 4B.0106 would be included in the CERCLA Remedial Design or Remedial Action Work Plan*		N.C.G.S. Ch.113A-157(5)
	Shall take all reasonable measures to protect all public and private property from damage caused by such activities.	Land-disturbing activity (as defined in N.C.G.S. Ch. 113A-52) of more than 1 acre of land – **relevant and appropriate**	15A NCAC 4B.0105
	Erosion and sedimentation control plan must address the following basic control objectives: (1) Identify areas subject to severe erosion, and off-site areas especially vulnerable to damage from erosion and sedimentation. (2) Limit the size of the area exposed at any one time. (3) Limit exposure to the shortest feasible time. (4) Control surface water run-off originating upgrade of exposed areas (5) Plan and conduct land-disturbing activity so as to prevent off-site sedimentation damage. (6) Include measures to control velocity of storm water runoff to the point of discharge.		15A NCAC 4B.0106
	Erosion and sedimentation control measures, structures, and devices shall be planned, designed, and constructed to provide protection from the run-off of 10 year storm.	Land-disturbing activity (as defined in N.C.G.S. Ch. 113A-52) of more than 1 acre of land – **relevant and appropriate**	15A NCAC 4B.0108
	Shall conduct activity so that the post-construction velocity of the ten year storm run-off in the receiving watercourse to the discharge point does not exceed the parameters provided in this Rule.		15A NCAC 4B.0109
	Shall install and maintain all temporary and permanent erosion and sedimentation control measures.		15A NCAC 4B.0113
Control of fugitive dust emissions	The owner/operator of a facility shall not cause fugitive dust emissions to cause or contribute to the substantive complaints or visible emissions.	Activities potentially generating excess fugitive dust emissions as defined in 15A NCAC 02D .0540 (a)(1) – **relevant and appropriate**	15A NCAC 02D .0540
Waste Characterization – Primary wastes (contaminated media) and Secondary wastes (wastewaters, spent treatment media, etc.)			
Characterization of *solid waste* (all primary and secondary wastes)	Must determine if solid waste is a hazardous waste using the following method: • Should first determine if waste is excluded from regulation under 40 CFR261.4; and • Must then determine if waste is listed as a hazardous waste under subpart D 40 CFR part 261.	Generation of solid waste as defined in 40 CFR 261.2 (incorporated by 15A NCAC 13A .0106) – **applicable**	40 CFR § 262.11(a) and (b)15A NCAC 13A .0107(a)
	Must determine whether the waste is (characteristic waste) identified in subpart C of 40 CFR part 261 by either: (1) Testing the waste according to the methods set forth in subpart C of 40 CFR part 261, or according to an equivalent method approved by the Administrator under 40 CFR §260.21; <u>or</u> (2) Applying knowledge of the hazard characteristic of the waste in light of the materials or the processes used.		40 CFR § 262.11(c) 15A NCAC 13A .0107(a)
	Must refer to Parts 261, 262, 264, 265, 266, 268, and 273 of Chapter 40 for possible exclusions or restrictions pertaining to management of the specific waste.	Generation of solid waste which is determined to be hazardous – **applicable**	40 CFR § 262.11(d)15A NCAC 13A .0107(a)
Determinations for management of hazardous waste	Must determine if the hazardous waste has to be treated before land disposed. This is done by determining if the waste meets the treatment standards in 40 CFR 268.40, 268.45, or 268.49 by testing in accordance with prescribed methods <u>or</u> use of generator knowledge of waste. This determination can be made concurrently with the hazardous waste determination required in 40 CFR 262.11. cited but worded differently.	Generation of RCRA hazardous waste for storage, treatment or disposal – **applicable**	40 CFR § 268.7(a)(1) 15A NCAC 13A .0112(a)
Determinations for management of hazardous waste	Must comply with the special requirements of 40 CFR § 268.9 in addition to any applicable requirements in 40 CFR § 268.7.	Generation of waste or soil that displays a hazardous characteristic of ignitability, corrosivity, reactivity, or toxicity for storage, treatment or disposal **– applicable**	40 CFR § 268.7(a)(1) 15A NCAC 13A .0112(a)

Federal and North Carolina Action-Specific ARARs			
Action	**Requirements**	**Prerequisite**	**Citation(s)**
con't	Must determine each EPA Hazardous Waste Number (waste code) applicable to the waste in order to determine the applicable treatment standards under 40 CFR 268 *et seq.* This determination may be made concurrently with the hazardous waste determination required in Sec. 262.11 of this chapter.	Generation of RCRA characteristic hazardous waste for storage, treatment or disposal – **applicable**	40 CFR § 268.9(a) 15A NCAC 13A .0112(a)
	Must determine the underlying hazardous constituents [as defined in 40 CFR 268.2(i)] in the characteristic waste.	Generation of RCRA characteristic hazardous waste (and is not D001 non–wastewaters treated by CMBST, RORGS, or POLYM of Section 268.42 Table 1) for storage, treatment or disposal – **applicable**	40 CFR § 268.9(a) 15A NCAC 13A .0112(a)
Characterization of industrial wastewater	Industrial wastewater discharges that are point source discharges subject to regulation under section 402 of the CWA, as amended, are not solid wastes for the purpose of hazardous waste management. [Comment: This exclusion applies only to the actual point source discharge. It does not exclude industrial wastewaters while they are being collected, stored or treated before discharge, nor does it exclude sludges that are generated by industrial wastewater treatment.]	Generation of industrial wastewater and discharge into surface water – **applicable**	40 CFR § 261.4(a)(2)
Waste Storage – Primary wastes (contaminated media) and Secondary wastes (wastewaters, spent treatment media, etc.)			
Storage of solid waste	All solid waste shall be stored in such a manner as to prevent the creation of a nuisance, insanitary conditions, or a potential public health hazard.	Generation of solid waste which is determined *not* to be hazardous – **relevant and appropriate**	15A NCAC 13B .0104(f)
	Containers for the storage of solid waste shall be maintained in such a manner as to prevent the creation of a nuisance or insanitary conditions. Containers that are broken or that otherwise fail to meet this Rule shall be replaced with acceptable containers.		15A NCAC 13B .0104(e)
Temporary accumulation of hazardous waste in containers	A generator may accumulate hazardous waste at the facility provided that: • waste is placed in containers that comply with 40 CFR 265.171–173; and • the date upon which accumulation begins is clearly marked and visible for inspection on each container; • container is marked with the words “hazardous waste”;	Accumulation of RCRA hazardous waste on site as defined in 40 CFR §260.10 – **applicable**	40 CFR § 262.16(b)(6); 15A NCAC 13A .0107(a) 40 CFR §262.17(a)(1); 15A NCAC 13A .0107(a)
Use and management of hazardous waste in containers	If container is not in good condition (e.g. severe rusting, structural defects) or if it begins to leak, must transfer waste into container in good condition.	Storage of RCRA hazardous waste in containers – **applicable**	40 CFR § 262.15(a)(1) 15A NCAC 13A .0107(a)
	Use container made or lined with materials compatible with waste to be stored so that the ability of the container is not impaired.		40 CFR § 262.15(a)(2) 15A NCAC 13A .0107(a)
	Containers must be closed during storage, except when necessary to add/remove waste. Container must not be opened, handled and stored in a manner that may rupture the container or cause it to leak.		40 CFR § 262.15(a)(4) 15A NCAC 13A .0107(a)
Storage of hazardous waste in container storage unit	Area must have a containment system designed and operated in accordance with 40 CFR §264.175(b).	Storage of RCRA–hazardous waste in containers with *free liquids* – **applicable**	40 CFR §264.175(a) 15A NCAC 13A .0109(j)
	Area must be sloped or otherwise designed and operated to drain liquid from precipitation, or Containers must be elevated or otherwise protected from contact with accumulated liquid.	Storage of RCRA–hazardous waste in containers that *do not contain free liquids* (other than F020, F021, F022, F023, F026 and F027) – **applicable**	40 CFR § 264.175(c)(1) and (2) 15A NCAC 13A .0109(j)
Closure performance standard for RCRA container storage unit	Must close the facility (e.g., container storage unit) in a manner that: • Minimizes the need for further maintenance; • Controls minimizes or eliminates to the extent necessary to protect human health and the environment, post–closure escape of hazardous waste, hazardous constituents, leachate, contaminated run-off, or hazardous waste decomposition products to the ground or surface waters or the atmosphere; and • Complies with the closure requirements of subpart, but not limited to, the requirements of 40 CFR 264.178 for containers.	Storage of RCRA hazardous waste in a container storage unit – **applicable**	40 CFR § 264.111 15A NCAC 13A .0109(h)

Federal and North Carolina Action-Specific ARARs			
Action	**Requirements**	**Prerequisite**	**Citation(s)**
Closure of RCRA container storage unit	At closure, all hazardous waste and hazardous waste residues must be removed from the containment system. Remaining containers, liners, bases, and soils containing or contaminated with hazardous waste and hazardous waste residues must be decontaminated or removed. [Comment: At closure, as throughout the operating period, unless the owner or operator can demonstrate in accordance with 40 CFR 261.3(d) of this chapter that the solid waste removed from the containment system is not a hazardous waste, the owner or operator becomes a generator of hazardous waste and must manage it in accordance with all applicable requirements of parts 262 through 266 of this chapter].	Storage of RCRA hazardous waste in a container storage unit with a containment system – **applicable**	40 CFR § 264.178 15A NCAC 13A .0109(j)
Treatment/Disposal of Wastes – Primary wastes (contaminated media) and Secondary wastes (wastewaters, spent treatment media, etc.)			
Disposal of solid waste	Shall ensure that waste is disposed of at a site or facility which is permitted to receive the waste.	Generation of solid waste intended for off-site disposal – **relevant and appropriate**	15A NCAC 13B .0106(b)
Disposal of RCRA hazardous waste in a land–based unit	May be land disposed if it meets the requirements in the table "Treatment Standards for Hazardous Waste" at 40 CFR 268.40 before land disposal.	Land disposal, as defined in 40 CFR268.2, of restricted RCRA waste – **applicable**	40 CFR § 268.40(a) 15A NCAC 13A .0112(d)
	All underlying hazardous constituents [as defined in 40 CFR 268.2(i)] must meet the Universal Treatment Standards (UTS), found in 40 CFR 268.48 Table UTS prior to land disposal.	Land disposal of restricted RCRA characteristic wastes (D001 – D043) that are not managed in a wastewater treatment system that is regulated under the CWA, that is CWA equivalent, or that is injected into a Class I nonhazardous injection well – **applicable**	40 CFR §268.40(e) 15A NCAC 13A .0112(d)
	To determine whether a hazardous waste identified in this section exceeds the applicable treatment standards of 40 CFR 268.40, the initial generator must test a sample of the waste extract or the entire waste, depending on whether the treatment standards are expressed as concentration in the waste extract or waste, or the generator may use knowledge of the waste. If the waste contains constituents (including UHCs in the characteristic wastes) in excess of the applicable UTS levels in 40 CFR 268.48, the waste is prohibited from land disposal, and all requirements of part 268 are applicable, except as otherwise specified.	Land disposal of RCRA toxicity characteristic wastes (D004 – D011) that are newly identified (i.e., wastes, soil, or debris identified by the TCLP but not the Extraction Procedure) – **applicable.** Note: D004-D011 are wastes having toxicity characteristics for metals	40 CFR § 268.34(f) 15A NCAC 13A .0112(c)
Disposal of RCRA–hazardous waste soil in a land–based unit (e.g. permitted landfill)	Must be treated according to the alternative treatment standards of 40 CFR 268.49(c) <u>or</u> according to the UTSs [specified in 40 CFR 268.48 Table UTS] applicable to the listed and/or characteristic waste contaminating the soil prior to land disposal.	Land disposal, as defined in 40 CFR § 268.2, of restricted hazardous *soils* – **applicable**	40 CFR § 268.49(b) 15A NCAC 13A .0112(d)
Disposal of RCRA wastewaters into CWA wastewater treatment unit	Are not prohibited, if the wastes are managed in a treatment system which subsequently discharges to waters of the U.S. pursuant to a permit issued under 402 of the CWA (i.e., NPDES permitted) unless the wastes are subject to a specified method of treatment other than DEACT in 40 CFR 268.40, or are D003 reactive cyanide.	Land disposal of hazardous wastewaters that are hazardous only because they exhibit a hazardous characteristic and are not otherwise prohibited under 40 CFR Part 268 – **applicable**.	40 CFR § 268.1(c)(4)(i) 15A NCAC 13A .0112(a)
Groundwater Remediation Wells			
Standards for pumps and equipment for recovery well	The pump and related equipment for the well shall meet the location, access, placement, priming and seal requirements identified in the cited regulations.	Design, construction, or operation of any recovery well (*not used for water supply*) – **applicable**	15A NCAC 02C .0109(a) thru 15A NCAC 02C .0109(j)
Performance standard for injection wells	No person shall construct, operate, maintain, convert, plug, abandon, or conduct any other injection activity in a manner that allows the movement of fluid containing any contaminant into underground sources of drinking water if the presence of that contaminant may cause a violation of any applicable groundwater quality standard specified in Subchapter 02L or may otherwise adversely affect human health.	Design, construction, or operation of any injection well – **applicable**	40 CFR § 144.12 15A NCAC 02C.0211(c)
Injection of substances into underground well	Remediation wells used to inject additives, treated groundwater, or ambient air for treatment of contaminated soil or groundwater may inject only additives determined by Department of Health and Human services not to adversely affect human health. *NOTE: Approval is considered "administrative"; however, determination is made through NCDEQ concurrence on remedy and approval of Remedial Design and Remedial Action Work Plan.*	Injection of fluids into or air into an underground well for the purposes of groundwater or soil remediation – **applicable**	15A NCAC 02C .0225(a)
	Rule requirements for other wells shall be treated as one of the injection well types in Rule .0209(5)(b) of this Section that the Director determines most closely resembles the equivalent hydrogeologic complexity and potential to adversely affect groundwater quality that most closely resembles the well. Director may permit by rule the emplacement or discharge of a fluid or solid into the subsurface for any activity that meets the definition of an "injection well" that the Director determines not to have the potential to adversely affect groundwater quality and does not fall under other rules in this Section. *NOTE: Approval is considered "administrative"; however, determination is made through NCDEQ concurrence on remedy and Remedial Design and Remedial Action Work Plan.*	Injection of substances into an underground well other than liquids or air – **applicable**	15A NCAC 02C .0230

Federal and North Carolina Action-Specific ARARs			
Action	**Requirements**	**Prerequisite**	**Citation(s)**
Reinjection of treated contaminated groundwater	Wells are not prohibited if injection is approved by EPA or a State pursuant to provisions for cleanup of releases under CERCLA or RCRA *as provided in the CERCLA document*.	Class IV wells [as defined in 40 CFR § 144.6(d)] used to re-inject treated contaminated groundwater into the same formation from which it was drawn – **relevant and appropriate**	40 CFR § 144.13(c) RCRA § 3020(b)
Design of Groundwater Remediation System that extracts and treats contaminated groundwater and reinjects the treated groundwater	The infiltration gallery(ies) or injection well(s) must be designed such that the infiltration gallery(ies) or injection well(s) shall not cause or contribute to: (1) the migration of contaminants into previously uncontaminated areas; (2) a violation of the groundwater standards at the compliance boundary (if discharge is within the compliance boundary of the disposal facility); and (3) a violation of the groundwater standards at the point of discharge (if discharge is not within the compliance boundary of the disposal facility).	Design criteria for injection well system where contaminated groundwater is extracted, treated, and reinjected into the same formation - **applicable**	15A NCAC 02T .1605(a)
	(b) There shall be provisions in the operating plan to ensure the quality of the treated effluent and hydraulic control of the system at all times when any portion of the system ceases to function (e.g. standby power capability, complete system-off status, or duplicity of system components).		15A NCAC 02T .1605(b)
	(c) Design shall include a minimum elevation protection of two feet above the 100-year flood elevation.		15A NCAC 02T .1605(c)
	(d) Flow equalization of at least 25 percent of the facility's permitted hydraulic capacity must be provided for facilities with fluctuations in influent flow which may adversely affect the performance of the system.		15A NCAC 02T .1605(d)
Injection zone determination	Shall specify the horizontal and vertical portion of the injection zone within which the proposed injection activity shall occur based on the hydraulic properties of that portion of the injection zone specified. No violation of groundwater quality standards specified in Subchapter 02L resulting from the injection shall occur outside the specified portion of the injection zone as detected by a monitoring plan approved by the Division. *NOTE: Injection zone will be specified in Remedial Design or Remedial Action Work Plan approved by NCDEQ.*	Installation of groundwater remediation wells (other than permitted by Rule) for *injection of additives* – **applicable**	15A NCAC 02C.0225(e)(2)
Mechanical integrity of remediation wells	All permanent injection wells require tests for mechanical integrity, which shall be conducted in accordance with Rule .0207 of this Section. An injection well has internal mechanical integrity when there is no leak in the casing, tubing, or packer. An injection well has external mechanical integrity when there is no fluid movement into groundwaters through vertical channels adjacent to the injection well bore.	Installation of groundwater remediation wells (other than permitted by Rule) for *injection of additives* – **applicable**	15A NCAC 02C.0225(h) 15A NCAC 0207(a) and (b)
Operation and maintenance of remediation well for injection	1. Unless permitted by this rule, pressure at the well head shall be limited to a maximum which will ensure that the pressure in the injection zone does not initiate new fractures or propagate existing fractures in the injection zone, initiate fractures in the confining zone, or cause the migration of injected or formation fluids outside the injection zone or area. 2. Injection between the outermost casing and the well borehole is prohibited. 3. Monitoring of the operating processes at the well head shall be provided for by the well owner, as well as protection against damage during construction and use.	Installation of groundwater remediation wells (other than permitted by Rule) for *injection of additives* – **applicable**	15A NCAC 02C.0225(i)(1)-(3)
Operation and maintenance of treatment system	Shall at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) which are installed or used. Proper operation and maintenance includes effective performance and adequate laboratory and process controls, including appropriate quality assurance procedures.	Operation of a well for *injection of additives* or groundwater underground – **applicable**	15A NCAC 02C .0211(k)
Monitoring of injection wells	Monitoring wells shall be of sufficient quantity and location so as to detect any movement of injection fluids, injection process byproducts or formation fluids outside the injection zone as determined by the applicant in accordance with Subparagraph (e)(2) of this Rule. The monitoring schedule shall be consistent with the proposed injection schedule, pace of the anticipated reactions, and rate of transport of the injectants and contaminants. *NOTE: The monitoring will be specified in a monitoring plan included as part of a CERCLA document (e.g., Remedial Design or Remedial Action Work Plan).*	Installation of groundwater remediation wells (other than permitted by Rule) for *injection of additives* – **applicable**	15A NCAC 02C.0225(e)(9)
	If affected, may require additional monitor wells located to detect any movement of injection fluids, injection process byproducts, or formation fluids outside the injection zone as determined by the applicant in accordance with Subparagraph (e)(2) of this Rule. If the operation is affected by subsidence or catastrophic collapse, the monitoring wells shall be located so that they will not be physically affected and shall be of an adequate number to detect movement of injected fluids, process byproducts, or formation fluids outside the injection zone or area.	Installation of monitoring wells in (or adjacent to) the injection zone *that may be affected by injection operations* – **applicable**	15A NCAC 02C.0225(j)(3)

Federal and North Carolina Action-Specific ARARs			
Action	**Requirements**	**Prerequisite**	**Citation(s)**
Groundwater Monitoring Well Installation, Operation, and Abandonment			
Implementation of groundwater monitoring system	Must install and implement a monitoring system to evaluate the effects of the discharge upon waters of the state, including the effect of any actions taken to restore groundwater quality, and the efficiency of any treatment facility. NOTE: *The Monitoring will be specified in a monitoring plan included as part of a CERCLA document (e.g., Remedial Design or Remedial Action Work Plan).*	Groundwater remediation activities – **applicable**	15A NCAC 02L .0110(a)
	Shall be constructed in a manner that will not result in contamination of adjacent groundwaters of a higher quality.	Installation of monitoring system to evaluate effects of any actions taken to restore groundwater quality, as well as the efficacy of treatment – **applicable**	15A NCAC 02L .0110 (b)
Construction of groundwater monitoring well(s)	No well shall be located, constructed, operated, or repaired in any manner that may adversely impact the quality of groundwater.	Installation of wells (including temporary wells, monitoring wells) other than for water supply **- applicable**	15A NCAC 02C.0108(a)
	Shall be located, designed, constructed, operated and abandoned with materials and by methods which are compatible with the chemical and physical properties of the contaminants involved, specific site conditions, and specific subsurface conditions.		15A NCAC 02C.0108(c)
	Monitoring well and recovery well boreholes shall not penetrate to a depth greater than the depth to be monitored or the depth from which contaminants are to be recovered. Any portion of the borehole that extends to a depth greater than the depth to be monitored or the depth from which contaminants are to be recovered shall be grouted completely to prevent vertical migration of contaminants.		15A NCAC 02C.0108(d)
	Shall be constructed in such a manner as to preclude the vertical migration of contaminants with and along borehole channel.	Installation of wells (including temporary wells, monitoring wells) other than for water supply - **applicable**	15A NCAC 02C.0108(f)
	The well shall be constructed in such a manner that water or contaminants from the land surface cannot migrate along the borehole annulus into any packing material or well screen area.		15A NCAC 02C.0108(g)
	Packing material placed around the screen shall extend at least one foot above the top of the screen. Unless the depth of the screen necessitates a thinner seal, a one foot thick seal, comprised of chip or pellet bentonite or other material approved by the Department as equivalent, shall be emplaced directly above and in contact with the packing material		15A NCAC 02C.0108(h)
	Grout shall be placed in the annular space between the outermost casing and the borehole wall from the land surface to the top of the bentonite seal above any well screen or to the bottom of the casing for open end wells. The grout shall comply with Paragraph (e) of Rule .0107 of this Section except that the upper three feet of grout shall be concrete or cement grout.		15A NCAC 02C.0108(i)
	All wells shall be grouted within seven days after the casing is set. If the well penetrates any water-bearing zone that contains contaminated or saline water, the well shall be grouted within one day after the casing is set.		15A NCAC 02C.0108(j)
	Shall be secured with a locking well cap to ensure against unauthorized access and use. Shall be equipped with a steel outer well casing or flush-mount cover, set in concrete, and other measures sufficient to protect the well from damage by normal site activities.		15A NCAC 02C.0108(k) and (l)
Construction of groundwater monitoring well(s) *con't*	The well casing shall be terminated no less than 12 inches above land surface unless all of the following conditions are met: (1) site-specific conditions directly related to business activities, such as vehicle traffic, would endanger the physical integrity of the well; and (2) the well head is completed in such a manner so as to preclude surficial contaminants from entering the well.		15A NCAC 02C.0108(n)
	Shall have permanently affixed an identification plate. The identification plate shall be constructed of a durable, waterproof, rustproof metal or other material approved by the Department as equivalent and shall contain the following information: (1) well contractor name and certification number; (2) date well completed; (3) total depth of well; (4) a warning that the well is not for water supply and that the groundwater may contain hazardous materials; (5) depth(s) to the top(s) and bottom(s) of the screen(s); and (6) the well identification number or name assigned by the well owner.		15A NCAC 02C.0108(o)
	Shall be developed such that the level of turbidity or settleable solids does not preclude accurate chemical analyses of any fluid samples collected or adversely affect the operation of any pumps or pumping equipment.		15A NCAC 02C.0108(p)

Federal and North Carolina Action-Specific ARARs			
Action	**Requirements**	**Prerequisite**	**Citation(s)**
	Shall be constructed in such a manner as to preclude the vertical migration of contaminants within and along the borehole channel.	Installation of temporary wells and all other non-water supply wells- **applicable**	15A NCAC 02C.0108(s)
Maintenance of groundwater monitoring well(s)	Every well shall be maintained by the owner in a condition whereby it will conserve and protect groundwater resources, and whereby it will not be a source or channel of contamination or pollution to the water supply or any aquifer.	Installation of wells (including temporary wells and monitoring wells) other than for water supply **- applicable**	15A NCAC 02C.0112(a)
	Broken, punctured, or otherwise defective or unserviceable casing, screens, fixtures, seals, or any part of the well head shall be repaired or replaced, or the well shall be abandoned pursuant to 15A NCAC 02C .0113		15A NCAC 02C.0112(d)
	All materials used in the maintenance, replacement, or repair of any well shall meet the requirements for new installation.		15A NCAC 02C.0112(c)
	No well shall be repaired or altered such that the outer casing is completed less than 12 inches above land surface. Any grout excavated or removed as a result of the well repair shall be replaced in accordance with Rule .0107(f) of this Section.		15A NCAC 02C.0112(f)
	Shall be abandoned by filling the entire well up to land surface with grout, dry clay, or material excavated during drilling of the well and then compacted in place; and	Permanent abandonment of wells (including temporary wells, monitoring wells, and test borings) other than for water supply less than 20 feet in depth and which do not penetrate the water table - **applicable**	15A NCAC 02C.0113(d)(1)
	Shall be abandoned by completely filling with a bentonite or cement - type grout.	Permanent abandonment of wells (including temporary wells, monitoring wells, and test borings) other than for water supply greater than 20 feet in depth and which do not penetrate the water table - **applicable**	15A NCAC 02C.0113(d)(2)
	All wells shall be permanently abandoned in which the casing has not been installed or from which the casing has been removed, prior to removing drilling equipment from the site.	Permanent abandonment of wells (including temporary wells) other than for water supply – **applicable**	15A NCAC 02C.0113(f)
Transportation of Wastes – Primary and Secondary Wastes			
Transportation of hazardous materials	Shall be subject to and must comply with all applicable provisions of the HMTA and HMR at 49 CFR 171–180.	Any person who, under contract with a department or agency of the federal government, transports "in commerce," or causes to be transported or shipped, a hazardous material – **applicable**	49 CFR § 171.1(c)
Transportation of hazardous waste *off site*	Must comply with the generator requirements of 40 CFR Sect. 262.20–23 for manifesting, Sect. 262.30 for packaging, Sect. 262.31 for labeling, Sect. 262.32 for marking, Sect. 262.33 for placarding and Sect. 262.40, 262.41(a) for record keeping requirements and Sect. 262.12 to obtain EPA ID number.	Preparation and initiation of shipment of RCRA hazardous waste off-site – **applicable**	40 CFR § 262.10(h) 15A NCAC 13A .0108
Transportation of hazardous waste *on–site*	The generator manifesting requirements of 40 CFR Sect. 262.20–262.32(b) do not apply. Generator or transporter must comply with the requirements set forth in 40 CFR § 263.30 and § 263.31 in the event of a discharge of hazardous waste on a private or public right-of-way.	Transportation of hazardous wastes on a public or private right–of–way within or along the border of contiguous property under the control of the same person, even if such contiguous property is divided by a public or private right-of-way – **applicable**	40 CFR § 262.20(f) 15A NCAC 13A .0108
Management of samples (i.e. contaminated soils and wastewaters)	Are not subject to any requirements of 40 CFR Parts 261 through 268 or 270 when: • The sample is being transported to a laboratory for the purpose of testing; • The sample is being transported back to the sample collector after testing; and • The sample collector ships samples to a laboratory in compliance with U.S.DOT, U.S. Postal Service, or any other applicable shipping requirements, including packing the sample so that it does not leak, spill or vaporize from its packaging.	Generation of samples of hazardous waste for purpose of conducting testing to determine its characteristics or composition – **applicable**	40 CFR § 261.4(d)(1)(i) and (ii) 15A NCAC 13A .0108 40 CFR § 261.4(d)(2) 15A NCAC 13A .0108
Institutional Controls for Contamination Left in Place			
Notice of Contaminated Site	Prepare and certify by professional land surveyor a survey plat which identifies contaminated areas which shall be entitled "NOTICE OF CONTAMINATED SITE". Notice shall include a legal description of the site that would be sufficient as a description in an instrument of conveyance and meet the requirements of N.C.G.S. 47-30 for maps and plans.	Contaminated site subject to current or future use restrictions included in a remedial action plan as provided in N.C.G.S. 143B-279.9(a) – **TBC**	NCGS 143B-279.10(a)
	The Survey plat shall identify: • The location and dimensions of any disposal areas and areas of potential environmental concern with respect to permanently surveyed benchmarks; • The type location, and quantity of contamination known to exist on the site; and • Any use restriction on the current or future use of the site.		NCGS 143B-279.10(a)(1)-(3)
	Notice (survey plat) shall be filed in the register of deeds office in the county which the site is located in the grantor index under the name of the owner.		NCGS 143B-279.10(b) and (c)

Federal and North Carolina Action-Specific ARARs			
Action	**Requirements**	**Prerequisite**	**Citation(s)**
	The deed or other instrument of transfer shall contain in the description section, in no smaller type than used in the body of the deed or instrument, a statement that the property is a contaminated site and reference by book and page to the recordation of the Notice.	Contaminated site subject to current or future use restrictions as provided in N.C.G.S. 143B-279.9(a) that is to be sold, leased, conveyed or transferred — **TBC**	NCGS 143B-279.10(e)

Notes:

ARAR = applicable or relevant and appropriate requirement

CFR = *Code of Federal Regulations*

CWA = Clean Water Act of 1972

DOT = U.S. Department of Transportation

EPA = U.S. Environmental Protection Agency

HMR = Hazardous Materials Regulations

HMTA = Hazardous Materials Transportation Act

NCAC = *North Carolina Administrative Code*

N.C.G.S = North Carolina General Statutes

NPDES = National Pollutant Discharge Elimination System

RCRA = Resource Conservation and Recovery Act of 1976

TBC = to be considered

UTS = Universal Treatment Standard

Appendix B
Acronyms and Abbreviations

Acronyms and Abbreviations

µg/kg	micrograms per kilogram
µg/L	micrograms per liter
AR	Administrative Record
ARAR	applicable or relevant and appropriate requirement
AS	air sparging
AST	aboveground storage tank
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
cis-1,2-DCE	cis-1,2-dichloroethene
COC	chemical of concern
CSM	conceptual site model
DNAPL	dense non-aqueous phase liquid
EE/CA	engineering evaluation/cost analysis
ELCR	expected lifetime cancer risk
EPC	exposure point concentration
ERA	ecological risk assessment
ERD	enhanced reductive dechlorination
FFA	Federal Facilities Agreement
FS	Feasibility Study
HHRA	Human Health Risk Assessment
HI	hazard index
HQ	hazard quotient
IRP	Installation Restoration Program
ISCO	in-situ chemical oxidation
LCH	lower Castle Hayne
LSA	Limited Site Assessment
LUC	land use control
LUCIP	Land Use Control Implementation Plan
MCB	Marine Corps Base
MCH	middle Castle Hayne
MCL	maximum contaminant level
mg/L	milligrams per liter
MNA	monitored natural attenuation
MSCC	Maximum Soil Contaminant Concentration
NA	natural attenuation
NAPL	non-aqueous phase liquid
Navy	Department of the Navy
NCDEQ	North Carolina Department of Environmental Quality
NCGWQS	North Carolina Groundwater Quality Standards
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
NTCRA	non-time-critical removal action

O&M	operation and maintenance
OSHA	Occupational Safety and Health Administration
OU	operable unit
PCE	tetrachloroethene
PP	Proposed Plan
PTW	principal threat waste
RA	remedial action
RAO	remedial action objective
RD	Remedial Design
RI	Remedial Investigation
ROD	Record of Decision
RSL	Regional Screening Level
SVE	soil vapor extraction
TCE	trichloroethene
UCH	upper Castle Hayne
USEPA	United States Environmental Protection Agency
USMC	United States Marine Corps
UST	underground storage tank
VC	vinyl chloride
VI	vapor intrusion
VIMS	vapor intrusion mitigation system
VISL	vapor intrusion screening level
VOC	volatile organic compound
ZVI	zero-valent iron

Appendix C
NCDEQ Concurrence Letter

ROY COOPER
Governor
MICHAEL S. REGAN
Secretary
MICHAEL SCOTT
Director

NORTH CAROLINA
Environmental Quality

April 4, 2019

NAVFAC Mid-Atlantic
NAVFAC MIDLANT EV34
Attn: Dave Cleland
9324 Virginia Avenue
Building N26, RM 3300
Norfolk, VA 23511-3095

RE: Concurrence with the 2019 Final Record of Decision (ROD) for OU #15, Site 88
MCB Camp Lejeune, NC
NC6170022580
Jacksonville, Onslow County, North Carolina

Dear Mr. Cleland:

The NC Superfund Section has received and reviewed the Final Record of Decision (ROD) for OU#15, Site 88 at MCB, Camp Lejeune dated April 1, 2019 and concurs with the selected remedy and it is protective of human health and the environment.

The State's concurrence is based solely on the information contained in the Revised Final ROD dated April 1, 2019 for Operable Unit #15, Site 88. Should we receive additional information that significantly affects the conclusions of the ROD, we may modify or withdraw this concurrence with written notice to the Naval Facilities Engineering Command for Camp Lejeune and the EPA Region IV.

If you have any questions or comments, please contact me, at (919) 707-8341 or email randy.mcelveen@ncdenr.gov

Sincerely,

James Bateson
Chief, Superfund Section

Cc: Qu Qi, NC Superfund Section, Electronic only
Charity Delaney, EMD/IR
Jennifer Tufts, USEPA

NORTH CAROLINA
Department of Environmental Quality

Response to Comments
Draft Record of Decision
Site 88
MCB Camp Lejeune, North Carolina

PREPARED FOR: Dave Cleland, NAVFAC Mid-Atlantic
Charity Delaney, MCB Camp Lejeune
Randy McElveen, NCDEQ
Jennifer Tufts, EPA Region 4

PREPARED BY: CH2M HILL, Inc. (CH2M)

DATE: April 1, 2019

The purpose of this document is to address comments and provide revisions to the Draft Record of Decision (ROD) for Site 88, Marine Corps Base (MCB) Camp Lejeune, North Carolina. The North Carolina Department of Environmental Quality (NCDEQ) and United States Environmental Protection Agency (EPA) Region 4 comments are listed below. Responses to comments are provided in bold.

NCDEQ Comments (dated February 18, 2019)

1. Please make the following recommended changes to the language regarding Site-wide plume stability as discussed on page 55 of the ROD.

   "The following lines of evidence ~~may~~ [will] be considered [and discussed with the regulatory agencies and all stakeholders] when transitioning from active treatment to MNA [and a decision made regarding whether to continue the selected remedy or initiate additional active treatment of the plume or transition to MNA]:

   • Plume stability:
     – COC concentrations above the cleanup levels not observed in perimeter and/or sentinel wells
     – COC concentrations in downgradient plume wells not statistically increasing, as determined by Mann-Kendall or similar trend analysis, for three successive sampling events
     – Decreasing or stable-to-decreasing concentrations of COCs in samples collected from near-source wells"

   The above clarifications are necessary due to the extremely high remediation goals (1000 times the Standards and hundreds of years to achieve Cleanup Levels after active remediation is completed.) There should be an imperative to discuss the results of the remedies with the regulatory agencies and all stakeholders after Active Remediation Goals are achieved to fully evaluate plume stability.

   Agreed. The ROD will be updated to reflect agency and stakeholder inclusion. The proposed language was edited as follows:

   "The following lines of evidence will be considered and discussed with the regulatory agencies and stakeholders when evaluating the transition from active treatment to MNA or an alternate treatment technology:…"

2. The last sentence at the bottom of page 55 and the top of page 56 is not complete. Also, the close parenthesis needs to be added to the text at the proper location after the sentence is completed. Please make appropriate corrections to this sentence or paragraph.

   The sentence was intended to be as follows: LUCs including, but not limited to, land use restrictions in the Base Master Plan, deed and/or lease restrictions, and administrative procedures to prohibit unauthorized aquifer use and intrusive activities (for example, excavation, well installation, or construction), require evaluation of VI if future changes in building or land use occur, and prohibit residential use will be implemented as part of the remedy to prevent exposure to the residual contamination on the site that exceeds the cleanup levels.

   This omission will be corrected.

3. Why did we remove the remedial goals for

   · Benzene (1 µg/L)
   · Naphthalene (6 µg/L)

   from Table A-1 on page 1 of 1 of Appendix A.

   Benzene and naphthalene were removed because they did not contribute to unacceptable risks to human health; however, these constituents are present at concentrations exceeding North Carolina Groundwater Quality Standards and, consequently, should be included as constituents of concerns for groundwater. This rationale will be explained in Section 2.7.3 and benzene and naphthalene be revised in Appendix A-1 and Tables 7 and 9.

4. Please explain why the Action-Specific ARAR, for Use and management of hazardous waste in containers, was changed from 15A NCAC 13A .0109 in the Feasibility Study (FS) to 15A NCAC 13A .0107 on page 2 of 6 of the ARARS Table A-2 in Appendix A of the ROD. Was it due to the provisions of the Hazardous Waste Generator Improvements Rule that took effect in North Carolina on March 1, 2018. Please explain.
   Yes, the updated citation is based on the provisions of the Hazardous Waste Generator Improvements Rule that took effect between the submittal of the FS and the ROD.

   The other ARARs additions and deletions from the FS to the ROD are understood since they were required for the specific remedies that are being proposed for the ROD and the rules for technologies that are not being applied in the ROD were removed from the ARARs as appropriate.

   Comment noted.

EPA Comments (dated March 7, 2019)

1. Section 2.6, Current and Potential Future Land and Water Uses, Page 26. At the end of the second paragraph please add, "However, under North Carolina's classification, the surficial and Castle Hayne aquifers are considered Class GA, a potential source of drinking water."

   This sentence will be added as requested.

2. Table 7, Groundwater COCs Requiring a Response Action, Page 39. Justification should be provided for applying a target cancer risk of 1.0 x10-4 for the groundwater VISLs. Please add a

footnote to the table that states, "PCE and TCE values are based on an HQ of 1.0, and vinyl chloride is based on a target cancer risk of 1.0 x10-4. The upper end of the risk range was selected for vinyl chloride because it was detected in sub-slab soil gas but not in indoor air indicating the pathway into indoor air is not complete."

The requested explanation will be added to the second footnote on Table 7 and will be updated to include benzene and naphthalene, as explained in the response to NCDEQ Comment #3.

3. Tables 8, VI Pathways of Concern and Table 9 Cleanup Levels, Page 39-40. The soil gas cleanup levels specified in Table 2 of the PP should be included in the ROD. The soil gas cleanup levels monitored during (and after) the remedial action, will indicate progress and success in remediating groundwater to ensure that remaining subsurface vapor sources will not pose unacceptable HH risk due to the VI pathway. Please add the soil gas cleanup levels to Tables 8 and 9. Also, to Table 8, please add a footnote that states, "PCE and TCE values are based on an HQ of 1.0, and vinyl chloride is based on a target cancer risk of 1.0 x10-4. The upper end of the risk range was selected for vinyl chloride because it was detected in sub-slab soil gas but not in indoor air indicating the pathway into indoor air is not complete."

   The soil gas cleanup levels have been updated to reflect target sub-slab and near-source soil gas concentrations for a target cancer risk of $1.0x10^{-4}$ and an HQ of 1.0 for a residential use scenario, as presented in the PP.

   The requested explanation will be added to the second footnote on Table 8.

4. Section 2.10.1 Description of Remedial Alternatives, Page 44. The timeframes required to meet cleanup levels after the active treatment portion of the remedy range from 128 to 259 years, which are not considered "reasonable timeframes" for meeting cleanup criteria as described by the NCP. The timeframe discussion should be followed with language that states, "If long-term monitoring data indicate that natural attenuation will require such long timeframes after active treatment is complete, optimization of the remedy, including additional injection events, may be required to increase the degradation rate of the remaining contaminants so that cleanup levels can be met in a reasonable timeframe."

   This statement will be added to the timeframe discussion as requested.

   In addition, EPA cannot agree to the active remediation goals that are associated with the long timeframes provided in Table 13 as part of a Final ROD. The Navy can move forward with finalizing the ROD in one of the following ways:

   a) Remove the active remediation goals. The values presented will not allow groundwater to meet cleanup levels/RAOs in a reasonable timeframe (~100 years), therefore EPA cannot agree to the active remediation goals and should be removed. The 'remedy optimization' language recommended above will provide a path forward for remediating groundwater within a reasonable timeframe.

   b) Calculate active remediation goals that will allow aquifer restoration in a reasonable timeframe, and determine the number of injections necessary to achieve the goals. The optimized remedy can be included as part of the selected remedy.

   c) Submit the Final ROD as an Interim ROD. For an Interim ROD, Table 13 can remain in the document with the active remediation goals/timeframes. The subsequent Final ROD could be MNA if it's determined cleanup levels will be met within a reasonable timeframe post active remediation, or a separate remedy may be selected if MNA alone is insufficient.

The ROD will be updated to remove the active remediation goals (option A).

5. Table 13, Active Remediation Goals and Time to Achieve Cleanup Levels, Page 44. Please modify "Time to Achieve Cleanup Levels…" to "Estimated Time to Achieve Cleanup Levels…" in the table.

   The column header will be revised as requested.

6. Section 2.11 Selected Remedy, Page 50. Please modify the next to last sentence to state, "After active treatment is complete in each zone, MNA will be implemented to monitor the COCs in groundwater until cleanup levels are attained and RAOs are satisfied."

   This sentence will be revised as requested.

7. Table A-2, Action Specific ARARs, Groundwater Monitoring Well Installation, Operation and Abandonment. Several monitoring well entries are missing and should be added to the table. See Site 49 Final ROD, Dec. 2013, ARAR entries, Monitoring Well Installation, Operation, and Abandonment.

   ARARs pertaining to construction, maintenance, and abandonment of groundwater monitoring wells will be added to Table A-2.

8. Table A-2, Action Specific ARARs, Institutional Controls for Contamination Left in Place. The prerequisites should be identified as 'TBC'.

   The specified prerequisites will be changed to TBC as requested.

NCDEQ Comments (dated March 19, 2019)

1. As discussed on page 46, should we state what percent the daughter products are reduced by, based on predictive modeling, if we reduce PCE to 160 times the NCAC 2L Groundwater Standards (112 ug/l)?

   Yes. A column will be added to Table 13 to indicate the correlating COC reduction percentage.

2. Please clarify the last sentence in the redline portion of the last paragraph at the bottom of page 52. "cleanup levels are attached and RAOs are satisfied". The statement doesn't fit the original part of the sentence.

   This sentence will be revised to "cleanup levels are attained and RAOs are satisfied."

EPA Comments (dated March 21, 2019)

1. Section 1.4.1, Assessment of the Site, Page 2. To be consistent with other statements later in the ROD, modify the last sentence to state, "After active treatment is complete in each zone, MNA will be implemented to monitor the COCs in groundwater until cleanup levels are attained and RAOs are satisfied."

   This sentence will be revised as requested.

2. Section 2.6, Current and Potential Future Land and Water Uses, Page 26. At the end of the paragraph, add the following NCP language since it's the basis for the RAOs in this remedy, "Under the NCP at 40 CFR §300.430(a)(1)(iii)(F), EPA expects to return usable ground waters to their beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site."

This language will be added as requested.

3. <u>Section 2.11.4, Statutory Determinations, Page 63. Preference for Treatment of a Principal Element</u> – the last sentence mentions 'sparging'. Since the remedy doesn't include sparging, please modify.

   The reference to sparging will be removed from this paragraph.

4. <u>Section 2.11. 4, Statutory Determinations, Page 63. Five-Year Review Requirements</u>– delete current text and add the following paragraph which is from the Declaration part of the ROD with an added sentence on revisiting the remedy in the event it's not protective:

   "Because this remedy will result in hazardous substances, pollutants, or contaminants remaining onsite in groundwater and soil gas above levels that allow for unlimited use and unrestricted exposure, a statutory review will be conducted within five years after the initiation of the RA to ensure that the remedy is, or will be, protective of human health and the environment in accordance with CERCLA Section 121(c) and the NCP at 40 Code of Federal Regulations (CFR) 300.430 (f)(4)(ii). If results of the five-year reviews reveal that the remedy is not protective of human health, additional RAs would be evaluated by the parties and implemented by the Navy."

   The language under Five Year Review Requirements will be replaced as indicated.

<u>EPA Comments (submitted via email dated March 29, 2019 and March 31, 2019)</u>

1. Please revise reasonable timeframe language as follows:

   > If ~~long-term~~ <u>Five-Year Review</u> monitoring data indicate that natural attenuation will ~~require such long~~ <u>result in groundwater restoration</u> timeframes <u>longer than 100 years</u> after active treatment is complete, optimization of the remedy, including additional injection events, ~~may~~ <u>will</u> be required to increase the degradation rate of the remaining contaminants so that cleanup levels can be met in a reasonable timeframe.

   The reasonable timeframe language will be revised as follows:

   If <u>Five-Year Review</u> monitoring data indicate that natural attenuation will <u>result in groundwater restoration</u> timeframes <u>longer than 100 years</u> after active treatment is complete, optimization of the remedy <u>will</u> be required to increase the degradation rate of the remaining contaminants so that cleanup levels can be met in a reasonable timeframe.

2. In Tables 10, 11, and 12, please change "5 to >120 years" to "5 to 100 years"

   Tables 10, 11, and 12 will be updated to reflect an MNA timeframe of 100 years.

3. <u>Page 59, Expected Outcomes of the Selected Remedy</u> - Modify the 1st sentence in next to last paragraph: MNA will be conducted after active ~~remediation goals are achieved~~ treatment <u>components are implemented and</u> until each COC is at or below its respective cleanup levels for four consecutive monitoring events.

   These revisions will be incorporated.

4. <u>Page 62, Protection of Human Health and the Environment</u>—Modify the 4th sentence: ~~Once active remediation goals are met~~ <u>After implementation of active treatment remedy components,</u> MNA will take effect to monitor the plume until contaminant concentrations ~~are such that would allow for unlimited use and unrestricted exposure~~ <u>attain cleanup levels and RAOs are achieved.</u> Modify last sentence: Once biodegradation can be maintained naturally and

further enhancements are not required, MNA will take effect to monitor the plume until contaminant concentrations ~~are such that allow for unlimited use and unrestricted exposure~~ attain cleanup levels and RAOs are achieved.

These revisions will be incorporated.